BRIGHAM YOUNG UNIVERSITY
SCIENCE BULLETIN

TENEBRIONIDAE BEETLES OF THE NEVADA TEST SITE

by

Vasco M. Tanner
and
Willis A. Packham

Biological Series — Vol. VI, No. 1

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FOREWORD

This is another of a series of major publications on desert ecology resulting from studies at the Nevada Test Site by the Brigham Young University Department of Zoology and Entomology in cooperation with the United States Atomic Energy Commission. Although some of the studies are the result of independent investigations by specialists who are not on our departmental staff, they are part of the major project initiated cooperatively by B.Y.U. and the AEC to determine the effect of nuclear detonations on the native animals of the Nevada Test Site.

Dorald M. Allred and
D Elden Beck
Project Supervisors

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TENEBRIONIDAE BEETLES OF THE NEVADA TEST SITE[1]

by

Vasco M. Tanner[2]

and

Willis A. Packham[3]

INTRODUCTION

In August 1959 Brigham Young University initiated an ecological study of the animals at the Nevada Test Site. As part of that study, emphasis was given to the ground-dwelling arthropods. One of the largest resulting collections was beetles in the family Tenebrionidae. These are herein described, and notes on their relative abundance, seasonal occurrence, and plant community relationships at the test site are included. The results reported here deal with those collected between August 1959 and July 1963.

The Nevada Test Site is situated in southern Nye County adjacent to northwestern Clark County and southwestern Lincoln County, about 70 miles northwest of Las Vegas, Nevada (refer to Allred, Beck, and Jorgensen, 1963a). It is approximately 40 miles long and 35 miles wide. Beetles were taken from three major areas of the test site—Frenchman Flat, Yucca Flat, and Rainier Mesa. The geography and ecology of the area were discussed in detail by Allred, Beck, and Jorgensen (1963a) in *Biotic Communities of the Nevada Test Site*. Their plant community designations of Larrea-Franseria, Grayia-Lycium, Salsola, Coleogyne, Atriplex-Kochia, Pinyon-Juniper and Mixed have been followed in this paper with slight modification. In Frenchman Flat *Lycium pallidum* occurs as a narrow, relatively pure stand which extends from the playa through the Larrea-Franseria. Inasmuch as the beetle fauna differed so much between this *Lycium* area and other areas in the Larrea-Franseria community where *Lycium* was much less abundant, it is herein considered as a separate community.

In Yucca Flat the vegetation in large areas in the Grayia-Lycium community has been disturbed and partially destroyed by nuclear weapons testing. Here also the beetle fauna differed. These areas are referred to herein as disturbed Grayia-Lycium in contrast to the Grayia-Lycium (undisturbed).

Beetles were collected at regular intervals in sunken can traps described and illustrated by Allred, *et al.* (1963a). Others were collected intermittently by hand from plants, small mammal burrows, under rocks, debris, bark, etc., and by use of an ultraviolet light.

Can traps usually were placed in two parallel lines 825 feet apart, each line with six cans spaced at 150-foot intervals. In the Mixed community an additional line of cans spaced at irregular intervals was used, and in the Pinyon-Juniper the lines of cans were 75 feet apart. In the disturbed Grayia-Lycium, however, four lines of traps radiated from ground zero (the point where a nuclear detonation took place). Each of these lines extended through an area completely denuded of native plants (but now invaded by *Salsola kali*), through adjacent zones of physically damaged plants, and terminated in areas of undisturbed vegetation. Each line consisted of thirty cans placed 265 feet apart.

Regular collections were made in each community for at least a year's period, except in the Pinyon-Juniper between November and March when snow cover prevented access to the study area. More incidental collections were made in some communities than in others. Therefore, for purposes of relative population comparisons, the total number of specimens collected in each community was adjusted according to the number of collection attempts.

The tenebrionids were preserved in 70% ethyl alcohol until pinned. Identified specimens have been deposited in the collections of Brigham Young University and other institutions and museums as indicated by Allred, *et al.* (1963b).

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ACCOUNTS OF THE SPECIES

The family Tenebrionidae in the United States is large and varied, with over 1,440 species and subspecies. The keys and literature to the family are scattered through many books and journals, and the taxonomic references to this family are voluminous. One of the early workers was John L. LeConte, who described many species (1851, 1858). The great morphologist, Lacordair, published a section on Tenebrionidae in his *Histoire Naturelle des Insecta* (1859). George H. Horn (1870) monographed the family and published additional treatises in 1874, 1878, and 1891. Thomas L. Casey was one of the prolific workers on this family. He revised the subfamilies Tentyriinae, Coniontinae, and the tribe Asidini (Casey 1907, 1908, 1912) and named many new genera and species. In 1909 Frank E. Blaisdell began a long series of publications on the tribe Eleodiini. From his works came many of the subspecific names used in this study. As far as can be determined, very little has been published on the ecology of the beetles of the family Tenebrionidae, although the taxonomic papers of Horn (1870) and LaRivers (1942, 1947, 1948) include notes on habitat and seasonal occurrence.

In the four years this study was in progress at the Nevada Test Site, 14,650 specimens representing 31 genera and 46 species and subspecies were collected. These are presented in the following check-list arranged by subfamily, tribe and genus. The number preceding the name indicates its rank in frequency of abundance at the test site. The numbers and letters following each name refer to the subfamily (1-1), tribe 1(1-1), genus 1(1-1)A and species 1(1-1)A-1. If the description of each category along with this code is followed, there should be very little difficulty in making a determination of a species.

Subfamily TENTYRIINAE (1-1)

Tribe Eurymetopini 1(1-1)

9 *Metoponium convexicolle* LeConte 1(1-1)A-1
24 *Hylocrinus laborans* Casey 1(1-1)B-2
33 *Steriphanus lubricans* Casey 1(1-1)C-3

Tribe Auchmobiini 2(1-1)

21 *Auchmobius subboreus* Blaisdell 2(1-1)A-4

Tribe Trimytini 3(1-1)

27 *Chilometopon abnorme* (Horn) 3(1-1)A-5

Tribe Epitragini 4(1-1)

29 *Metopoloba bifossiceps* Casey 4(1-1)A-6

Tribe Triorophini 5(1-1)

6 *Triorophus laevis politus* Casey 5(1-1)A-7

Tribe Edrotini 6(1-1)

3 *Edrotes orbus* Casey 6(1-1)A-8

Tribe Araeoschizini 7(1-1)

2 *Araeoschizus sulcicollis* Horn 7(1-1)A-9

Tribe Anepsiini 8(1-1)

22 *Anepsius brunneus* Casey 8(1-1)A-10

Tribe Cryptoglossini 9(1-1)

16 *Cryptoglossa verrucosa* LeConte 9(1-1)A-11
5 *Centrioptera muricata* LeConte 9(1-1)B-12

Subfamily ASIDINAE (1-2)

Tribe ASIDINI 1(1-2)

11 *Pelecyphorus pantex* Casey 1(1-2)A-13
24 *P. semilaevis* (Horn) 1(1-2)A-14
19 *Euschides luctatus* (Horn) 1(1-2)B-15
17 *Trichiasida acerba* (Horn) 1(1-2)C-16

Tribe CRANIOTINI 2(1-2)

35 *Craniotus blaisdelli* Tanner 2(1-2)A-17

Subfamily ELEODINAE (1-3)

Tribe ELEODINI 1(1-3)

14 *Trogloderus costatus nevadus* LaRivers 1(1-3)A-18
26 *Embaphion elongatum* Horn 1(1-3)B-19
10 *Eleodes carbonaria immunis* LeConte 1(1-3)C-20
12 *E. obscura sulcipennis* Mannerheim 1(1-3)C-21
8 *E. grancicollis valida* Boheman 1(1-2) C-22
4 *E. hispilabris sculptilis* Blaisdell 1(1-3)C-23
31 *E. longipilosa* Horn 1(1-3) C-24
1 *E. armata* LeConte 1(1-3)C-25
25 *E. armata pumila* Blaisdell 1(1-3)C-26
34 *E. nigrina* LeConte 1(1-3)C-27
32 *E. dissimilis nevadensis* Blaisdell 1(1-3)C-28
31 *E. longicollis* LeConte 1(1-3)C-29
28 *E. tenebrosa* Horn 1(1-3) C-30
30 *E. brunnipes brevisetosa* Blaisdell 1(1-3)C-31
25 *E. extricata frigida* LaRivers 1(1-3)C-32

Subfamily CONIONTINAE (1-4)

Tribe CONIONTINI 1(1-4)

34 *Sphaeriontis dilatata* (LeConte) 1(1-4)A-33
20 *Eusattus dubius* LeConte 1(1-4)B-34
13 *E. agnatus* Casey 1(1-4)B-35
24 *Coniontis nevadensis carsonica* Casey 1(1-4)C-36
36 *Coniontellus argutus* Casey 1(1-4)D-37

Subfamily PEDININAE (1-5)

Tribe BLAPSTINI 1(1-5)

23 *Blapstinus vandykei* Blaisdell 1(1-5)A-38
34 *B. pubescens* LeConte 1(1-5)A-39
7 *Notibius substriatus* Casey 1(1-5)B-40
18 *Conibiosoma elongatum* (Horn) 1(1-5)C-41

Subfamily OPATRINAE (1-6)

Tribe LEICHENINI 1(1-6)

33 *Anemia californica* Horn 1(1-6)A-42

Subfamily TENEBRIONINAE (1-7)

Tribe TENEBRIONINI 1(1-7)

36 *Coelocnemis punctata* LeConte 1(1-7)A-43
33 *Alaephus nevadensis Tanner*, n. sp. 1(1-7)B-44
24 *Eupsophulus castaneus* Horn 1(1-7)C-45

Subfamily HELOPINAE (1-8)

Tribe HELOPINI 1(1-8)

15 *Helops attenuatus* LeConte 1(1-8)A-46

CLASSIFICATION OF THE TENEBRIONIDAE COLLECTED AT THE NEVADA TEST SITE

In this study the salient characteristics of the subfamilies, tribes, genera and species of the Tenebrionidae collected at the Nevada Test Site are presented in as simple a terminology as possible. It is hoped that these keys will be an aid to the student and layman in understanding and learning about this large, interesting family of beetles. Some technical terms will of necessity be used, but with the aid of the accompanying drawings (Figs. 1-11), we believe that the descriptions and terminology may be understood.

The family Tenebrionidae is the largest family of beetles in the superfamily or assemblage of widely diverse families known as the Cucujoidea. The members of this family are commonly known as "Darkling Beetles" and are prevalent in the western United States, where they have become well adjusted to the dry desert conditions.

We are indebted to LeConte, Horn, Casey, Blaisdell, Bradley, Arnett and others for the use of their studies in the preparation of the following keys. We have selected, rearranged and added to the keys of these noted coleopterists. Rather than develop a short couplet key which is not easily used or understood by those not familiar with tenebrionid morphology, we have included rather lengthy characterizations of the several categories used in this classification.

The following suggestions are given to those who may use these keys. In order to determine

the species to which a given tenebrionid beetle may belong.

A. First determine to which one of the eight subfamilies the specimen belongs. (1-1) to (1-8).

B. Then, decide to which tribe of that subfamily the specimen belongs. I(1-1), etc.

C. Once it is placed in the proper tribe, one will not have too much difficulty in assigning it to the correct genus, e.g. I(1-1)A.

D. Many of the genera are monotypic. One need only turn to the page of the text and find the description of the species in question, e.g. I(1-1)A-1. If there are more than one species reported for a genus, a key to the different species will be found under the genus heading.

The drawings of a representative species taken at the test site have the main structures labeled. Reference to these labeled drawings should help in understanding the terms used in the keys.

The Family Tenebrionidae

The family Tenebrionidae may be recognized and separated from other Heteromera Coleoptera as follows:

> Front and middle tarsi five-jointed (Fig. I); the hind tarsi four-jointed (Fig. I); anterior coxal cavities closed behind (Fig. II); ventral abdominal segments four and five, in part connate (Fig. II); tarsal claws simple, the penultimate joint (Fig. I) of the tarsi not spongy beneath.

Species of eight subfamilies are represented in the collections made at the test site.

KEY TO THE SUBFAMILIES

(1-1) Subfamily Tentyriinae

Ventral segments of the abdomen entirely of a horny substance; middle, or mesothoracic coxae without trochantins; labrum or upper lip scarcely visible. Female genitalia quadrato-triangular in shape, valvifer elongate, twice as long as wide; anal plate well developed, stylus rudimentary or entirely absent in some species. Male apicale longer than the basale; genital fossa large, widely open, apicale sides of basale inflexed ventrally in apical half, connecting surface broadly membranous, sides scleritized.

(1-2) Subfamily Asidinae

Epistoma, or lower face between the mouth and eyes (Fig. I) truncated, with the margin cut into sinuses; labrum well developed, mandibles thick, punctate, wide apically, with tip bifid, antennae with segments nine and ten wider than the eleventh which is imbedded in the concave apex of the eleventh; mentum large to moderate in size, attached to a gular extension which may in some genera fill the entire buccal opening; prothorax much wider than the head, and narrower than the elytra; legs relatively small, given to show movements. Genera and species subject to considerable variations. Female genitalia strongly scleritized, coxites and valvifers elongate, styli small; the terminal abdominal segments of the female are capable of being protruded to a remarkable length. Male aedeagus slender and elongate; apicale is as long as the basale and four times as wide (See figures I and II).

(1-3) Subfamily Eleodinae

The principal characters of the above subfamily are these: mesocoxae have visible trochantins (Fig. II); the ventral abdominal segments are entirely corneous; eyes not prominent, more or less transverse, always emarginate in front; next to the last joint of tarsi entire, not bilobed; hind joint of antennae usually longer than the following; hind coxae transverse, never oblique; tarsi spinose or setose beneath; elytra widely embracing the body. The genitalia of the male is elongate flaxseed-shaped, apicale triangular with sides evenly arcuate, especially in the middle one-third, dorsal surface with an oval, slightly impressed semi-membranous area. Valvifers narrowly inflexed ventrally. The female genital segments similar in structure throughout the subfamily (See figures I and II).

(1-4) Subfamily Coniontinae

Middle coxae with visible trochantins. Labrum prominent, in great part visible. The abdominal intercoxae process acute and triangular. The mentum moderately emarginate, the ligula prominent and emarginate. The apicale of the male genitalia is elongate, several times as long

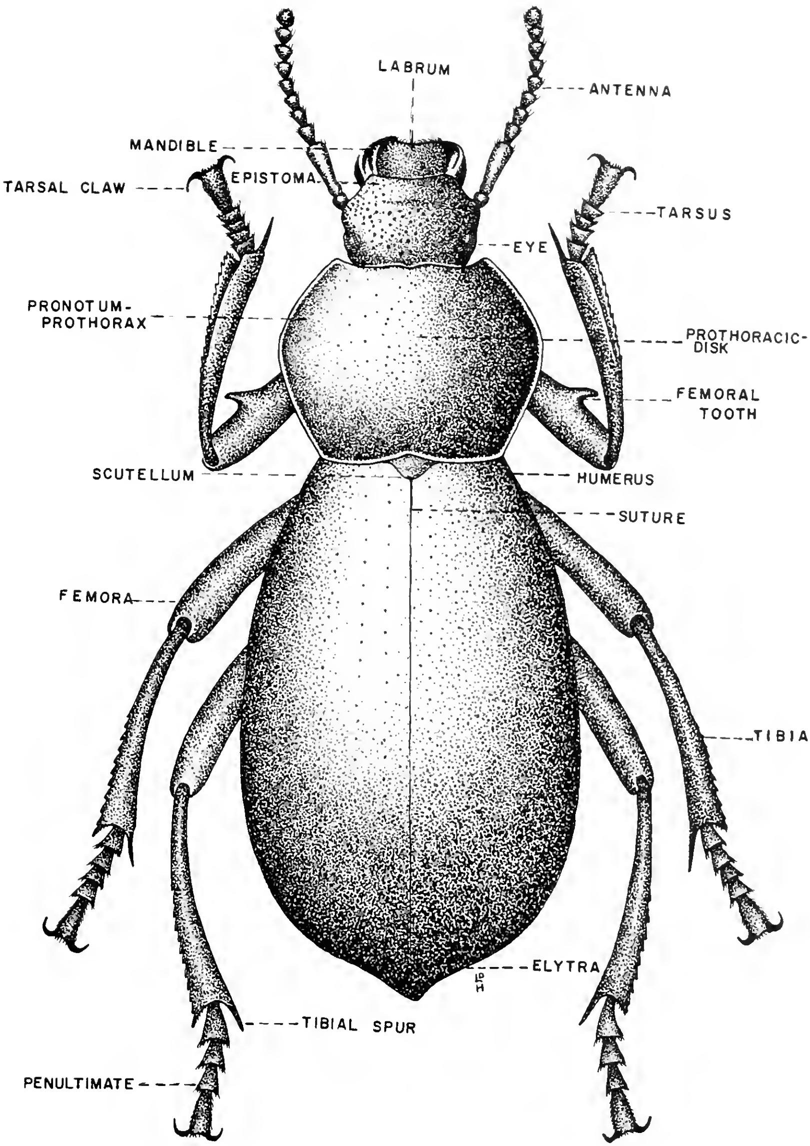

Figure I. *Eleodes grandicollis valida* Boheman, dorsal view.

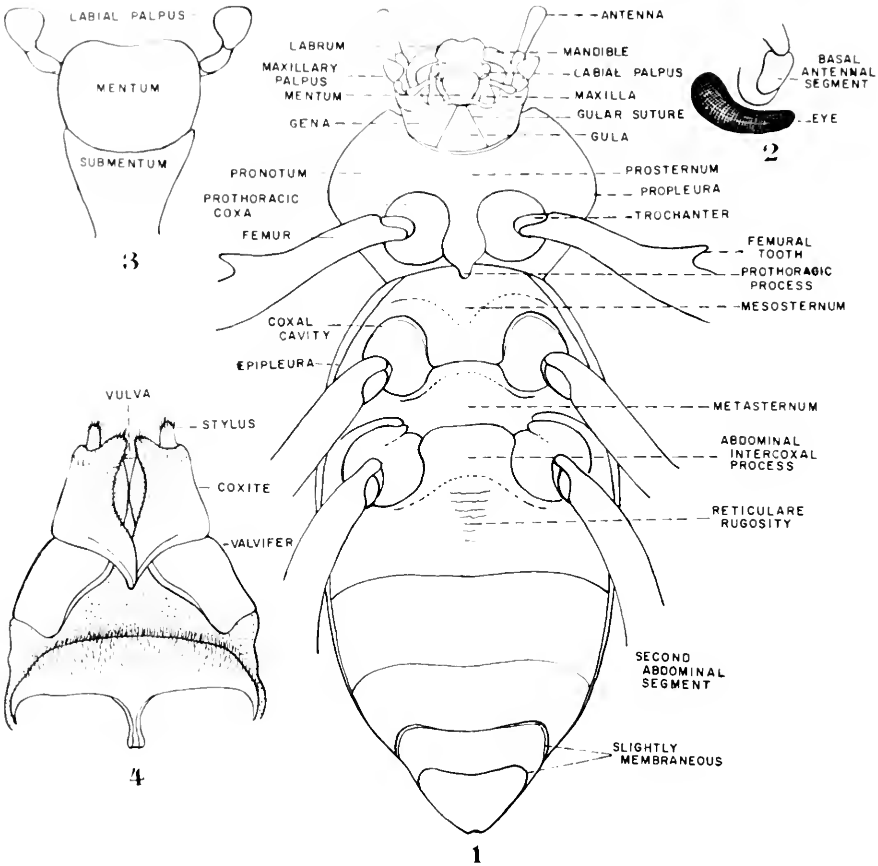

Figure II. *Eleodes grandicollis valida* Boheman, ventral view.

as wide, parallel in basal one-half, thence broadly arcuate and gradually convergent to apex, the latter emarginate at middle; valvifer short, twice as long as wide, distinctly shorter than the apicale. Female genitalia elongate with bacula as supports in the valvifers; coxites divided, stylus obsolete.

(1-5) Subfamily Pedininae

Body oval, not very convex; epistoma emarginate covering the base of the mandibles; labrum or upper lip prominent; mentum generally trilobed in front, small; ligula or central part of the lower lip prominent, eyes transverse, sometimes divided, elytra embracing feebly the sides of the abdomen; middle coxae with distinct trochantin; intercoxal process of abdomen truncate; anterior and sometimes the middle tarsi of the male dilated, and spongy beneath; hind tarsi sometimes pubescent and spinous.

(1-6) Subfamily Opatrinae

Body oval, head received by the thorax as far as the eyes, which are transverse, strongly emarginate and coarsely granulated, epistoma emarginate, extending down over the mandibles, labrum prominent, mentum small, ligula prominent, or slightly emarginate, maxillae exposed; elytra with narrow epipleurae (Fig. II), anterior coxae transverse or rounded.

(1-7) Subfamily TENEBRIONINAE

Beetles of this subfamily have bodies that are elongated, head prolonged, not received in the thorax as far as the eyes, which are transverse and emarginate, epistoma truncate, not separated from the labrum by a clypeus. Antennae with eleven joints, external ones broadened; mentum small, elytra feebly covering the sides of the abdomen, epipleurae narrow; middle coxae with noticeable trochantin; legs long, tarsi clothed beneath with silky golden or coarse pubescence.

(1-8) Subfamily HELOPINAE

Front of head with a leathery or horny margin or a leathery band between the front and labrum; sides of the front obliquely elevated; eyes transverse, emarginate and coarsely granulated; antennae thickened externally; mentum small; ligula prominent; sides of the prothorax separated by a margin from the disk, elytra with narrow epipleurae; middle coxae with distinct trochantin; tarsi slender, head not deflexed.

CHARACTERISTICS OF THE TRIBES, GENERA, AND SPECIES

(1-1) Subfamily TENTYRIINAE

Species from nine tribes of Tentyriinae are included in this report. Each tribe and the genera are characterized below. The species of each genus are described in the text of this study.

I(1-1) Tribe EURYMETOPINI

Middle coxae without trochantin; mentum very large, concealing both ligula and maxillae; anterior tibiae with two terminal spurs, not toothed externally near the middle; mandibles never grooved externally; posterior coxae more or less separated, the abdominal process acute to broadly rounded; elytra not embracing the sides of the body, the inflexed parts occupied wholly by the epipleura; mentum hexagonal, apex emarginate or sinuate; front without a prolonged epistoma clasped by the mandibles, the right mandible at least generally with a tooth which clasps the labrum only. Antennae slender, outer four segments broader; scutellum well developed; body generally winged, though often apterous.

The following three genera, *Metoponium*, *Hylocrinus* and *Steriphanus*, each represented by a single species, were collected at the test site.

1(1-1)A. Genus *Metaponium* may be characterized as follows:

> Anterior tibia produced externally at tip; eyes large, head with a distinct supra-orbital ridge or keel; epistoma never emarginate; mandibles ridged externally above; antennae slender, extending about to the base of the prothorax, last four joints broader compressed, the eleventh as long as the tenth or longer and pointed; scutellum distinct; elytra never strongly rugose and usually with distinct serial punctures; tarsi beneath with long, stiff setae; prothorax generally fully as wide as the elytra.

In 1907 Col. Casey described many species of *Metaponium* from Arizona and California. The senior author spent considerable time in June, 1964 studying the Casey collection and species of this genus. It is our opinion that the Casey complex of species in this genus must be revised before dependable reference to species of this genus can be made. We are therefore considering specimens of this genus as *convexicolle* LeConte 1(1-1)A-1. For a description of this species see page 16.

1(1-1)B. Genus *Hylocrinus* has the following characteristics:

> Anterior tibia not externally prolonged at tip, antennae long and slender, eyes large, not deeply emarginate; body elongate, parallel; surface glabrous; tarsi with sparse, stiff setae beneath.

A single species, *laborans* Casey, 1(1-1)B-2, belonging to this genus was collected at Mercury. The species description is given on page 17.

1(1-1)C. Genus *Steriphanus* has the following characteristics:

> Body oval, convex, glabrous, devoid of hind wings; tarsi spinulose or sparsely and very coarsely setose beneath; normal, subcylindrical; the anterior nearly straight as usual; frontal margin generally feebly sinuato-truncate, not evidently biemarginate. A single species, *lubricans* Casey 1(1-1)C-3 is described on page 17.

2(1-1) Tribe Auchmobiini

Middle coxae without trochantin, mentum very large, concealing both ligula and maxillae; anterior tibiae with two terminal spurs, not toothed externally near the middle; mandibles never grooved externally, posterior coxae more or less narrowly separated, the abdominal process acute to broadly rounded, elytra not embracing the sides of the body, the inflexed parts occupied wholly by the epipleura, mentum hexagonal, with the apex more or less distinctly emarginate, front with the epistoma (absolutely) prolonged, epistomal lobe not clasped by the mandibles, which are folded beneath it out of sight from above. Antennae gradually enlarged and compressed outwardly.

The only genus in this tribe is *Auchmobius*, 2(1-1)A, which was revised by Blaisdell in 1934. At this time he described seven new species. The Mercury species is considered by us to be *subboreus* Blaisdell 1(1-1)A-1. See the text, page 17, for description of this species.

3(1-1) Tribe Trimytini

Similar to Auchmobiini except that the epistomal lobe is clasped by the superior external ridge of the mandibles; antennae filiform, generally with the last four joints larger; scutellum well developed as in Eurymetopini; body winged or apterous, the metasternum with or without ante-coxal grooves.

3(1-1)A. Genus *Chilometopon* has the following characteristics:

> Outer ridge of the mandibles very narrow with a small dentiform protuberance at the base; body elongate, convex glabrous, fully winged; eyes large, prominent and only slightly emarginate anteriorly; tarsi long, the basal joint of the posterior variable; prothorax always narrowed toward the base, and widest before the middle; last antennal joint elongate, sometimes extremely so.

One species, *abnorme* (Horn) 3(1-1)A-5, is described on page 18.

4(1-1) Tribe Epitragini

Middle coxae without trochantin; mentum very large, concealing both ligula and maxillae; anterior tibiae with two terminal spurs; not toothed externally near the middle; mandibles never grooved externally; posterior coxae narrowly separated, abdominal process acute to broadly rounded; elytra not embracing the sides of the body, mentum transversely parallelogramic, the apex very broadly arcuate from side to side and not sinuate at the middle, generally much more transverse.

4(1-1)A. Genus *Metopoloba* has the following characteristics:

> Prosternum horizontally produced posteriorly, the tip received within a large deep mesosternal excavation; eyes large but not prominent, generally finely faceted and but feebly emarginate anteriorly; tarsi with sparse, short, stiff spiniform setae beneath the posterior, at least, devoid of denser and finer pubescence; supra-orbital ridges strong, eyes coarsely faceted; body elongate, pointed behind, basal joint of the hind tarsi at least equal in length to the fourth and usually longer; sculpture rather coarse and sparse, surface polished.

The species *bifossiceps* Casey 4(1-1)A-6, is described on page 18.

5(1-1) Tribe Triorophini

Middle coxae without trochantin; mentum large, concealing both ligula and maxillae; anterior tibiae with two terminal spurs, not toothed externally near the middle; mandibles never grooved externally; posterior coxae narrowly separated, the abdominal process acute to broadly rounded; elytra embracing the sides of the body, the inflexed parts not wholly occupied by the epipleura.

5(1-1)A. Genus *Triorophus* has the following characteristics:

> Epistomal lobe parallel, very prominent, angulate at apex, clasped toward base by the swollen basal parts of the mandibles; the latter stout, each with a strong dorsal tooth clasping the labrum; eyes transverse, emarginate anteriorly; prothorax margined at the sides; elytra inflated, with abbreviated series of coarse punctures, epipleura narrow; legs long, tarsi with sparse spinules beneath; lateral lobes of front tuberculate; sides of pronotum with a distinct marginal bend, its base not bisinuate.

The species *laevis* LeConte, subspecies *politus* Casey 5(1-1)A-7 is described on page 19.

6(1-1) Tribe Edrotini

Middle coxae without trochantin. Mentum very large, concealing both ligula and maxillae; anterior tibiae with terminal spurs, not toothed externally near the middle; mandibles never grooved externally; posterior coxae widely sep-

arated, the abdominal process broadly truncate; mesosternum without ante-coxal grooves; the body wingless; elytra frequently costulate; mesosternum elevated, flat, abutting closely and on the same plane against the apex of the flattened prosternal process; hind coxae transversely oval.

6(1-1)A. Genus *Edrotes* has the following characteristics:

Body rounded, convex, with conspicuous erect hairs; head large, epistomal lobe quadrate, with its sides parallel and sinuate, and apex broadly angulate nearly as in *Trioro-phus;* mentum transversely hexagonal, the apex trisinuate; eyes small, convex, prominent, and unemarginate; antennae long and slender, outer joints larger, the eleventh pyriform and long; prothorax with prominent and acute apical angles, strongly transverse; scutellum obsolete; elytra inflated and widely embracing the body beneath; epipleurae short; legs long, slender, the hind tarsi short, sparsely spinose and not at all grooved beneath, with long flying hairs above as on the femora and tibiae externally; hind coxae transverse, separated by less than their own width.

Description of the species *orbus* Casey 6(1-1)A-8, is on page 19 of the text.

7(1-1) Tribe ARAEOSCHIZINI

Middle coxae without trochantin; mentum generally small in size, never concealing both the ligula and maxillae; elytra without true epipleura; anterior coxae separated; antennae moderately long, thick, filiform and perfoliate, usually scaley, free; legs short and stout.

7(1-1)A. Genus *Araeoschizus* has the following characteristics:

Body elongate, convex, hind body pedunculate without humeral angles, the hind wings wanting; head elongate-oval, clypeus large; mentum rather large, flat, broadly truncate at apex; mandibles bifid at tip; eyes completely divided, coarsely faceted. The upper part elongate, sunken deeply between the prominent lateral margin and a strong supra-orbital ridge; antennae about as long as the head and half the prothorax, prothorax cordate, small; scutellum triangular scarcely passing the basal declivity of the elytra; coxae globular, moderately separated; legs short, stout, tarsi short, claws small, slender and arcuate.

Sulcicollis Horn 7(1-1) A-9, which is a very common species in this area, is described on page 20.

8(1-1) Tribe ANEPSIINI

Middle coxae with trochantin; labrum scarcely visible; tarsi spinose beneath; antennae not filiform; anterior tibiae broadly dilated.

8(1-1)A. Genus *Anepsius* has the following characteristics:

Body rather stout, convex, glabrous; head trapezoidal, clypeus broadly and feebly sinuate towards the middle; eyes basal, more rounded and less coarsely faceted, usually divided by the thick anterior canthus; antennae slender, almost as long as the head and prothorax, third joint longer than the second; prothorax four-fifths wider than long; elytra equal in width to the prothorax, two and one-half times as long, oval, the sides evenly arcuate; legs short, slender, the anterior tibiae broadly dilated at apex, with the spurs distinct; tarsi short, sparsely spinose beneath.

Brunneus Casey 8(1-1)A-10 was the only species of this genus collected at Mercury. It is described on page 21.

9(1-1) Tribe CRYPTOGLOSSINI

Middle coxae with trochantin; labrum scarcely visible; tarsi spinose beneath; antennae not filiform; anterior tibiae slender. Eyes present; emarginate, reniform. Posterior margin of the last two abdominal segments semi-circularly emarginate.

Two genera are represented in the specimens taken at Mercury. They may be separated by the following key:

1. Last antennal segment truncate, smaller than the tenth ... 9(1-1)A *Cryptoglossa*
2. Last antennal segment oval, pointed, nearly as large as the tenth .... 9(1-1)B *Centrioptera*

A description of the species *Centrioptera muricata* LeConte, 9(1-1)B-12, is on page 23. *Cryptoglossa verrucosa* LeConte, 9(1-1)A-11 is described on page 23.

(1-2) Subfamily ASIDINAE

Two tribes of this subfamily are represented in collections from the Nevada Test Site.

1(1-2) Tribe Asidini

Body ovate, apterous, head narrowed behind the eyes, which are transverse and kidney-shaped, epistoma very short, mentum large; antennae eleven segmented, elytra embracing widely the flanks of the abdomen, epipleurae indistinct, middle coxae with distinct trochantin; metasternum short, with the episterna wide; hind coxae moderately separated, intercoxal process of abdomen obtuse; legs with tibial spurs distinct, tarsi setose, but not sulcate beneath.

Three genera are represented in this tribe.

1(1-2)A. Genus *Pelecyphorus* has the following characteristics:

> Mentum not entirely filling the buccal opening and always placed upon a rather evident pedicle formed by a gular prolongation; ligula small, generally flat, angularly emarginate to subtruncate and strongly retractile, usually hidden under the mentum, the latter always clearly separated from the closed mandibles; last joint of the maxillary palpi variable in size in the sexes; prosternum deflexed, body diversely sculptured, very much larger in size; tarsi with short and inconspicuous spiniform hairs beneath; base of the prothorax truncate or arcuate-truncate; head and prothorax generally smaller, giving the body a markedly different habitus; elytra each with distinct ridges as shown in Figure XIII.

Two species collected may be separated as follows:

1. Edge of pronotum unevenly scalloped, tuberculate, narrow; elytra very ventricose and tuberculate; outer coxa rather fine but strong, the inner very fine and subobsolete ..... Fig. XIII, 1(1-2)A-13 *pantex* Casey
   See page 24 for description.
2. Edge of pronotum not scalloped, coarsely, sparsely and unevenly punctured, the sides narrowly reflexed; elytra elongate-oval, with distinct marginal costa, each with three nearly straight parallel, moderately elevated costa, the surface between the suture and first costa shining, the remainder opaque
   Fig. XIV, 1(1-2)A-14 *semilaevis* (Horn)
   See page 25 for description.

1(1-2)B. Genus *Euschides* has the following characteristics:

> Mentum not entirely filling the buccal opening and always placed upon a pedicle formed by a gular prolongation, ligula large, tumid, angularly incised; mentum always separated from the closed mandibles, thus leaving the maxillary cardo exposed in part; prosternum deflexed posteriorly between the coxae; last joint of the maxillary palpi large and scalene in male, smaller in the female; base of the prothorax broadly lobed, becoming anteriorly oblique toward the sides, basal angle obtuse, sometimes evident but never prominent.

One species *luctatus* (Horn) 1(1-2)B-15 reported; see description on page 26 of text.

1(1-2)C. Genus *Trichiasida* has the following characteristics:

> Mentum not filling the buccal opening and placed on a pedestal formed by a gular prolongation; ligula large, tumid, angularly incised; mentum separated from the closed mandibles, leaving the maxillary cardo exposed in part, prosternum deflexed posteriorly between the coxae. Last joint of the maxillary palpi differing but little sexually, never more than recti-triangular in the male; antennae more rapidly enlarged distally, the tenth joint with the usual two widely separated tomentose spots at the tip; elytra without true costae, the elevated lines when present having more or less the nature of narrow and accentuated obtuse ridges; body pubescent; mentum small, gular pedicle long and well developed; antennae slender; basal angles of prothorax never prominent; anterior tibiae serrulate externally, the outer angle at tip strongly everted and acutely spiniform.

One species *acerba* (Horn) 1(1-2)C-16; see page 26 for description.

2(1-2) Tribe Craniotini

Middle coxae without trochantin; mentum large, concealing both ligula and maxillae; anterior tibiae with two terminal spurs, not toothed externally near the middle; posterior coxae widely separated; the abdominal process broadly truncate; body wingless; elytra frequently costulate; metasternum not elevated, discontinuous with the prosternum; hind coxae small, oval, much abbreviated transversely; eyes finely faceted; legs long and slender; female genitalia of the compact type, which is Asidini in nature.

2(1-2)A. Genus *Craniotus* has the following characteristics:

Body narrow anteriorly, inflated elytra; sparse to dense pubescence on the body; head small, projection at the sides anterior to the eyes extend beyond one-third the width of the head; transverse groove behind the epistome; mandibles bifid at tip, folding beneath the labrum; mentum large, sinuate at apex and emarginate at base; antennae long and slender, the third segment much elongated, the eleventh not free but small and received within the apex of the tenth; prothorax transversely suboval; scutellum elongate; elytra embracing the sides of the body, epipleurae narrow, disappearing before the middle of the abdomen; anterior coxae separated; metasternum short, convex at the sides; femora and tibiae long, slender and subcylindric, hind tarsi rather short, slender, and with long hairs above and short stiff spines beneath. Female genitalia of the elongate type (Fig. XVII, 2-3).

For description of the species, *blaisdelli* Tanner 2(1-2)A-17, collected on the test site, see page 27.

(1-3) Subfamily ELEODINAE

Ventral segments three and four with coraceous hind margin; front entirely corneous; first joint of tarsi moderate or elongate, never very short tarsi, not compressed; eyes not prominent, more or less transverse, always emarginate in front; anterior tibiae alone or none dilated; penultimate joint of tarsi entire; anterior coxae rounded; middle coxae with trochanter; antennae perfoliate, third joint longer than the following; hind coxae transverse, never oblique; fourth segment of maxillary palpus triangular or securiform; epipleura attaining the sutural angle; tarsi spinose or setose beneath; elytra widely embracing the body.

1(1-3) Tribe Eleodini

Body oblong, apterous, head prominent; epistoma covering the base of the mandibles at the sides; labrum prominent; mentum small, trilobed, inserted upon a gular pedicle; maxillae exposed, maxillary palpi with the last joint securiform, not very large; eyes transverse, reniform; antennae eleven jointed with the outer segments rounded, equal; elytra embracing widely the flanks of the abdomen, epipleurae narrow; middle coxae with large trochantin, side pieces attaining the coxal cavities; metasternum short, episterna narrow, epimera distinct; hind coxae widely separated; intercoxal process of abdomen rectangular; third and fourth ventral segments not prolonged behind at margin. Legs long; anterior femora frequently toothed; tibial spurs distinct; tarsi channelled and setose beneath.

Key to the genera:

1. Sides of the epistoma not dilated, margin straight or sinuate, converging anteriorly 2

   Sides moderately dilated, margin arcuate .... 1(1-3)A *Trogloderus*

2. Epipleura attaining the humeral angles, broader at base, more or less gradually narrowing to apex, occupying only a part of the inflexed portion of the elytra; buccal processes of the genae not produced .... 1(1-3)C *Eleodes*

   Epipleura very narrow, not attaining the humeral angles .... 1(1-3)B *Embaphion*

1(1-3)A. Genus *Trogloderus* has the following characteristics:

Body elongate, rough, opaque; eyes transverse and reniform; head pierced with closely set, small holes; front prolonged, covering the labrum, sides dilated and reflexed; surface briefly convex at middle, transversely impressed with a small deep fovea on the vertex; antennae with third segment as long as the two following; prothorax emarginate in front, rounded on the sides, basal angles prominent; disc coarsely oribate; elytra with the suture and four costae each side acutely elevated; intercoxal process of first abdominal segment broader than long; under surface strongly granulate; anterior femorae armed with a small to broad tooth; front tibiae curved and serrate on the outer edge; tarsi setose.

This species, *costatus nevadus* LaRivers 1(1-3)A-18 is described on page 29.

1(1-3)B. Genus *Embaphion* has the following characteristics:

Thorax and elytra always acutely and sometimes broadly margined, margin more or less reflexed; epipleurae always narrow, rarely defined front (Figs. I and II) inflexed sides of the elytra, except at apex, where they are always well defined, not suddenly widened at base and never attaining the humeral angles of the elytra. Blaisdell made the following observation on the characteristics of this genus: "The above characters are distinctive of the genus and are not observed elsewhere in Eleodini."

One species of this genus was collected at the test site. See page 29 of this report for a description of *elongatum* Horn, 1(1-3)B-19.

The genus *Eleodes* 1(1-3)C has the following characteristics:

> Mentum trilobed, middle lobe large and convex, apical joint of labial and maxillary palpi triangular, suture between epistoma and front distinct, eyes reniform, antennae with eleven segments, the last three usually compressed. Prothorax variable in shape and sculpture in some species prolonged into a cuada behind, epipleurae distinct. Legs fairly long, femora not strongly clavate, in some species armed in one or both sexes with teeth, Tarsi usually channeled and setose beneath, spurs of the middle and hind tibiae well developed.

The genus *Eleodes*, because of the large numbers of species referred to it, has been separated into thirteen subgenera. For the list and characteristics of these subgenera see Tanner's paper (1961), Checklist and New Species of *Eleodes*, pp. 60-61.

The species of *Eleodes* collected at the test site belong to six of the thirteen subgenera which may be separated by means of the following key:

Subgenus *Melaneleodes*

Anterior femora armed only in the male or mutic; anterior tibial spines dissimilar in the sexes; femora mutic.

1(1-3)C-20 *carbonaria immunis* LeConte

This is the only species of *Melaneleodes* we have collected on the test site. A description and discussion of the species will be found on page 29 of this report.

Subgenus *Eleodes*

Anterior femora at least, armed in both sexes (except in *caudifera* and *longipilosa* where teeth are abortive).

The species and subspecies of this subgenus may be separated as follows:

1. Body elongate; elytra strongly sulcate; intervals quite strongly convex, smooth, with a single series of irregularly, distantly spaced, feebly muricate punctures, which become decidedly muricate on the apical declivity. Sulci about equal in width to the intervals, with closely placed muricate punctures which become more densely placed toward apex; inflex sides of the elytra obsoletely sulcate and irregularly muricately punctured. Size, males, 25 to 31 mm in length; width 9 to 14 mm
obscura sulcipennis Mann. 1(1-3)C-21
Description on page 30 of report.
2. Body large, oblong oval, black and shining, head twice as wide as long, punctation irregular, denser at the periphery. Antennae short and stout, reaching to the posterior fourth of the prothorax, third joint equal in length to the next two taken together; pronotum widest at about the middle, disc smooth and shining, surface finely and sparsely punctate, punctures arranged in distinct unimpressed series; epipleurae narrow, gradually narrowing from the base to the apex; abdomen sparsely punctate, with some reticulare rugosity; legs not long but stout; anterior femora in both series armed with an acute tooth; female genitalia of the compact type (Fig. II-4); size: males 26 to 29 mm in length, 10 to 12 mm in width; females, 27 to 30 mm in length, 10 to 12 mm in width, Figs. 1 and 2
grandicollis valida Boh. 1(1-3)C-22
Description on page 31 of report.
3. Body elongate, ovate, integument dull and thick, black in color, frequently reddish along the suture; head and thorax more or less shining. Elytra slightly convex, sulci opaque and deep, intervals strongly convex and shining; antennae long, reaching the base of the prothorax; pronotum widest at the middle; disc smooth, finely sparsely punctate; epipleurae gradually narrowing from base to apex; abdomen smooth, finely punctulate and rugulose; fifth segment more strongly punctate; legs slender; anterior femora armed with an acute tooth in both sexes. Size: males 18 to 22 mm in length, 7 to 9 mm in width; females 19 to 24 mm in length, 8 to 10 mm in width
hispilabris sculptilis Blais. 1(1-3)C-23
Description on page 32 of text.
4. Body elongate, surface sparsely clothed with long, black hairs; caudate;
longipilosa Horn 1(1-3)C-24
Description on page 32 of report.
5. Body large, elongate suboval to sub-

fusiform-ovate; dull black in color, all the femora armed with long acute spines; elytra moderately striate .... *armata* LeConte 1(1-3)C-25
Description on page 33 of text.

6. Body smaller, punctation fine and sparse, except on head; pronotum slightly wider than long, sides almost straight. Femoral teeth smaller and acute .... *armata pumila* Blais. 1(1-3)C-26
Description on page 33 of text.

Subgenus *Metablapylis*

Anterior tibial spurs similar in the sexes. Tarsi similar in the sexes, or nearly so. Middle lobe of the mentum small; anterior tarsi comparatively simple beneath, groove entire. Lateral lobes of the mentum fully exposed; sculpturing comparatively simple; femora mutic.

The two following species of *Metablapylis* may be characterized as follows:

1. Body elongate, usually about three times as long as wide. Head less than twice as long as wide, antennae moderate in length; eleventh segment ovate, truncate at tip; pronotum widest at or just in front of the middle, surface finely, densely and irregularly punctate, elytra widest at the middle, surface with fine punctures, usually arranged without order, and more or less striate; epipleurae widened beneath the humeri, then gradually narrowing to apex; legs moderate in length, mutic and stout. .... *nigrina* LeConte 1(1-3)C-27
This species is described on page 34 of this study.

2. Body cylindrico-fusiform, black, somewhat depressed, smooth, elytra striae rather distant; pronotum finely, but distinctly and sparsely punctulate; tibiae and tarsi with reddish-brown setae; spinules and tarsal claws strongly developed ....
dissimilis nevadensis Blais. 1(1-3) C-28
Description of this species on page 34 of this report.

Subgenus *Steneleodes*

Anterior tarsi dissimilar in the sexes. Species not usually pubescent, rarely so. Form elongate usually large; first joining of the anterior tarsi slightly thickened at tip beneath, bearing a small transverse tuft of yellowish or brownish modified spinules which interrupt the groove in the male; simple in the females.

The following is a brief characterization of the only species of *Steneleodes* taken at the test site:

Body elongate to elongate fusiform, black head twice as long as wide, finely punctate; antennae stout, pronotum widest at the middle; disc evenly convex, sparsely punctulate; sides finely margined; elytra elongate; base truncate; humeri obtuse; surface irregularly and evenly punctate; epipleurae rather wide at the humeri, gradually narrowing to apex; femora not densely punctate, the anterior mutic in both sexes ....
..... *longicollis* LeConte 1(1-3)C-29
For further discussion of this species see page 34 of this report.

Subgenus *Blapylis*

Form short ovate, moderate in size to small, robust (elongate and depressed in *tibialis*); anterior tarsi of male with first two or three joints feebly thickened at tip beneath and clothed with dense silken or brownish tufts, obliterating the groove; joints simple with grooves entire in female, femora mutic.

The two species of this subgenus may be separated as follows:

1. Body oblong-oval, two-and-a-third times longer than wide; head twice as wide as long; antennae with four outer joints feebly compressed, third joint equal to the next two taken together; pronotum finely and densely punctate, widest at the middle and evenly arcuate from apex to base; elytra sculpturing consisting of small shiny tubercles arising from an opaque base .... *tenebrosa* Horn 1(1-3)C-30
Description on page 34 of report.

2. Body robust, convex, coarsely and densely sculptured; color dull black, legs dark brown; head large, two-thirds as wide as the prothorax, densely punctate; antennae longer than the head and prothorax, third joint four times as long as wide; prothorax evenly convex, coarsely, deeply and confluently punctate; elytra coarsely, densely, asperately punctate ....
brunnipes brevisetosa Blais. 1(1-3)C-31
See page 35.

Subgenus *Lithelcodes*

Form ovate, moderate in size, less robust; first joint of the anterior tarsi more or less thickened and slightly more prominent ventrally than the others, pubescent tuft variable, most evident in *extricata;* male first joint with a minute tuft of silken pubescence at tip beneath.

1(1-3)C-32 *extricata frigida* LaRivers

This is the only species of *Lithelcodes* thus far taken at the test site. For additional comments on it see page 35 of this report.

(1-4) Subfamily CONIONTINAE

1(1-4) Tribe Coniontini

Body oval or globose, apterous; epistoma covering the base of the mandibles; labrum prominent; mentum moderate, emarginate, gular pendunele short or almost obsolete; ligula prominent, emarginate; maxillae exposed; eyes transverse, small elytra usually with narrow epipleurae; anterior coxae subtransverse; middle coxae with distinct trochantin, side pieces of mesothorax attaining the coxal cavities; metasternum short; hind coxae approximate; intercoxal process of abdomen acute; tibial spurs long, tarsi spinous beneath; the first joint of hind tarsi long.

1(1-4)A. Genus *Sphaeriontis* has the following characteristics:

Elytra widely embracing the sides of the body, the epipleura variable; anterior tibiae with everted external angle at apex; basal joint of anterior tarsi long; prothorax always prolonged at the sides and enveloping the humeri; scutellum nearly obsolete; epipleura narrow, occupying much less than the entire inflexed sides of the elytra; epipleura gradually becoming wider basally, sometimes extending to the sides of the elytra at base; sides of the elytra always obtusely rounded in sections, never acutely margined; antennae slender, dilated apically; intercoxal process obtuse, the coxae more widely separated throughout; body more broadly rounded, very convex, the sculpture more muricate; propleura with more conspicuous hairs.

Dilatata LeConte 1(1-4)A-33 is the only species of this genus collected at the test site. Description of this species is on page 35 of report.

1(1-4)B. Genus *Eusattus* has the following characteristics:

Similar in characteristics to *Sphaeriontis* except the intercoxal process of the abdomen is acute, the coxae throughout narrowly separated, body oblong-oval to parallel, moderately convex, propleura with or without bristling hairs.

Two species of this genus, *dubius* and *agnatus*, collected at Mercury may be separated as follows:

1. A small species; length 7.8 to 8.5 mm; width 4.2 to 4.6 mm. Body elongate, convex, polished; prothorax two and one-half times as wide as its median length; elytra narrow and elongate, almost a third longer than wide, punctures fine, but distinct; anterior tibiae only feebly serrulate externally .... *dubius* LeConte 1(1-4)B-34
   For further information on this species see page 36 of this report.
2. A larger species; length 8.9 to 9.8 mm; width 5.1 to 5.7 mm. Body broadly oblong-oval, moderately convex, subglabrous; prothorax not two and one-half times as wide as its median length; elytra elongate, as wide as the prothorax, parallel, surface feebly rugose, with sparse small muricate punctures; anterior tibiae strongly sinuate externally beyond the middle .... *agnatus* Casey 1(1-4)B-35
   This species is discussed on page 36 of the report.

1(1-4)C. Genus *Coniontis* has the following characteristics:

Elytra narrowly embracing the sides of the body, the epipleura constantly narrow and occupying the entire inflexed part; the basal joint of the anterior tarsi short, obliquely truncate at tip; prothorax variable at base, but generally more truncate; scutellum well developed, triangular; posterior angles of the prothorax strongly posteriorly produced; palpi more elongate than usual, last three joints of the antennae moderately dilated; basal joint of the anterior tarsi longer than the next two combined; obliquely prominent internally at tip, two to four transverse, rapidly diminishing in size.

Nevadensis carsonica Casey 1(1-4)C-36 is the only species of this genus collected at the test site. See page 36 of the text for description of the species of this genus.

1(1-4)D. Genus *Coniontellus* has the following characteristics:

This genus is similar to *Coniontides*, except that the posterior angles of the prothorax are feebly produced posteriorly, the thoracic base frequently subtruncate; eyes completely divided; body smaller, the legs and antennae shorter.

A single species of *Coniontellus argutus* Casey, 1(1-4)D-37 was collected. See page 37 of text for species description.

(1-5) Subfamily PEDININAE

1(1-5) Tribe Blapstini

Body oval; eyes completely divided; epistoma emarginate, the inflexed part of the elytra is composed entirely of the epipleurae; mentum not trilobed in front; dilation of the anterior tarsi of the male feeble; presence or absence of a fringe of setae along the lateral edges of the body.

1(1-5)A. Genus *Blapstinus* has the following characteristics:

Scutellum triangular, separating the elytra at base, the hind wings frequently well developed and the anterior tarsi of the male dilated as a rule; base of the prothorax bisinuate; anterior tibiae straight; pubescence simple; body usually oblong or oblong-oval, the sides not fimbriate; anterior tibiae simple.

Two species of this genus may be separated with the aid of the following:

1. Small species. Length 5.0 to 5.1 mm, width 2.5 to 2.6 mm. Color nigra piceous, frontal margin, labrum and legs more or less rufous; pubescence fairly dense, decumbent and confined to the intervals; head small widest just before the eyes; epistome emarginate over the labrum; pronotum about two-fifths wider than long; disc densely and evenly punctate; elytra twice as long as wide; striae distinct, punctures small; legs moderate in length and stoutness .... *vandykei* Blais. 1(1-5)A-38
   See page 37 of report for discussion of this species.
2. Large species. Length 6.4 to 6.5 mm. Width 3.0 to 3.1 mm. Color deep reddish brown; pubescence yellowish, dense and decumbent on head, prothorax and elytra; upper portion of eyes large, round and flat; punctation on head and prothorax dense and deep; distal three segments large and oval; legs moderate in length, first and fourth tarsal segments about equal in length .... *pubescens* LeConte 1(1-5) A-39
   This species is discussed on page 37 of this report.

1(1-5B. Genus *Notibus* has the following characteristics:

Eyes entirely divided; scutellum very short and broad, not entering the disc of the elytra; apterous; male tarsi not dilated; prothorax laterally densely fimbriate; anterior tibiae broadly triangular and compressed; body stout, oblong-oval.

One species, *Notibius substriatus* Casey 1(1-5)B-40, described on page 37 of this study.

1(1-5)C. Genus *Conibiosoma* has the following characteristics:

Eyes entirely divided; scutellum very short and broad, not entering the disc of the elytra; apterous; male tarsi not dilated; prothorax laterally densely fimbriate; anterior tibiae narrow, non-fossorial; body narrow and parallel. *Conibiosoma elongatum* (Horn), 1(1-5)C-41.

A description of this monotypic species will be found on page 38 of this text.

(1-6) Subfamily OPATRINAE

1(1-6) Tribe Leichenini

Specimens of this tribe have the fourth segment of the maxillary palpus elongate-oval; more or less finely acuminate.

1(1-6)A. Genus *Anemia* has the following characteristics:

Anterior tibiae not bent; vestiture not composed of short coarse recumbent hairs and long, erect, very robust bristles; anterior tibiae strongly dentate or produced externally at or near the apex; eyes completely divided, or extremely nearly so; epipleura entire; anterior tibiae short, triangular.

This genus is also a monotypic one. See page 38 for description of *Anemia californica* Horn, 1(1-6) A-42.

(I-7) Subfamily TENEBRIONINAE

I(I-7) Tribe Tenebrionini

Body elongate, apterous, or winged, head prolonged, front dilated on the sides, covering the base of the mandibles, antennae gradually thickened externally, elytra embracing feebly the sides of the abdomen, anterior coxae globose; legs long, tibial spurs small, hind margin of third and fourth ventral segments subcoriaceous.

I(I-7)A. Genus *Coelocnemis* has the following characteristics:

Tarsi with fine, usually silken pubescence beneath; outer segments of antennae with disc-like expansions connected by a stock passing nearly through their centers; antennae shorter than head and thorax; epipleura not attaining the tips of elytra; intercoxal process of abdomen broad, truncate.

The description of *C. punctata* LeConte, I(I-7)A-43 will be found on page 39 of this study.

I(I-7)B. Genus *Alaephus*:

Tarsi spinose or setose beneath; antennae elongate, slender, palpi long, tarsi slender; mentum emarginate. A single species of this genus taken at Mercury is closely related to *pallidus* Horn.

See page 39 of this text for description of *Alaephus nevadensis* Tanner n. sp. I(I-7)B-44.

I(I-7)C. Genus *Eupsophulus*:

This genus is similar to *Alaephus* differing in that the mentum is truncate in front. One species, *castaneus* Horn I(I-7)C-45. See page 40 for description.

(I-8) Subfamily HELOPINAE

I(I-8) Tribe Helopini

I(I-8)A. Genus *Helops*:

Body glabrous. Outer segments of antennae compressed; labrum prominent, clypeal membrane always visible; head usually prolonged behind the eyes; elytra feebly embracing the body. Epipleurae entire, anterior coxae globular; tarsi densely pubescent beneath; mesosternum short; intercoxae process broad or oval, never acute at tip.

One apterous species *attenuatus* LeConte, I(I-8)A-46 is described on page 40 of this study.

SYSTEMATIC AND ECOLOGICAL DISCUSSION OF THE SPECIES OF TENEBRIONIDAE COLLECTED AT THE NEVADA TEST SITE

I(I-1)A-1 *Metoponium convexicolle* LeConte

References. LeConte, Ann. Lyc. N. H. N. Y., V, 1851, pp. 125-216. Casey, Proc. Wash. Acad. Sci., IX, 1907, p. 309.

Morphological Characteristics. Length 6 to 7.5 mm; form stout; oblong; rather convex; chestnut brown to deep reddish black. Head somewhat coarsely and closely punctate; supraorbital carina prominent. Antennae fairly long and slender, the last four segments lightly compressed and dilated. Pronotum about as wide as the elytra; rather evenly arcuate, converging slightly more anteriorly than posteriorly; punctures strong laterally and becoming finer medially; scutellum transverse and oval. Elytra obtusely rounded at tip, coarse punctures in series which become confused toward the base. Legs short and stout.

Plant Community Relationships. A total of 277 specimens was collected. These were most abundant in the disturbed Grayia-Lycium with about one-ninth this number in Larrea-Franseria and one-fourth in Salsola. A few were collected in the Grayia-Lycium and Mixed communities, but none was found in Atriplex-Kochia, Coleogyne, or Pinyon-Juniper.

Seasonal Activity. This species was collected from February to December, but was most abundant from April through June. There was a decline in numbers collected during July and August followed by another population peak in September and October. In the disturbed Grayia-Lycium the period of activity was from February through December, whereas in Larrea-Franseria, Lycium, and Salsola it did not begin until March and April and lasted only until October. In the Larrea-Franseria, activity of this species stopped in August.

Comments. At the time Casey (1907) established this genus he was the author of all its

members except two species, *M. abnorme* and *M. convexicolle,* which had previously been named by LeConte. Since then, Blaisdell described four more species. Because Casey believed that there was little or no variation in a species, he named many new ones that today are considered synonyms. Representatives from our series were studied by Dr. Spilman at the National Museum and the senior author who compared them with the specimens in the Casey collection. Until this genus is revised and the validity of the Casey species determined, we propose to report this species as *convexicolle.* This was the ninth most common species at the site.

1(1-1)B-2 *Hylocrinus laborans* Casey

Reference. Casey, Proc. Wash. Acad. Sci., IX, 1907, p. 337.

Morphological Characteristics. Length 6 to 8 mm; oblong-oval, rather convex; varies from dull to shining; reddish brown. Head finely and densely punctate; slight supra-orbital carina; eyes large, protruding, and entire; antennae reaching the base of the pronotum. Pronotum finely and densely punctate throughout; anterior apical angle short and broadly acute. Elytra wider than pronotum; twice as long as wide, punctures feeble, close-set, and arranged in lines between the intervals. Legs slender, relatively short compared to the body.

Plant Community Relationships. A total of 31 specimens was collected The greatest number occurred in the Grayia-Lycium community, with about two-thirds of this number in the Lycium and Mixed communities. Disturbed Grayia-Lycium areas supported slightly fewer than half, whereas Larrea-Franseria had only one-third as many as Grayia-Lycium. Salsola had one-ninth as many as disturbed Grayia-Lycium. They were not found in Atriplex-Kochia, Coleogyne or Pinyon-Juniper.

Seasonal Activity. This species first appeared in June. Beetles were most abundant during June and July, and persisted in smaller numbers until December. In August there was a decline in activity which increased again in September. Observed activity ceased in September in all communities except the Mixed. There was no apparent activity in October or November but in December activity was noted again in the Mixed community.

Comments. This genus was established by Casey (1907) to contain sixteen species he described from the Great Basin and contiguous areas. A comparison of specimens in question was made by the senior author with the Casey species. It is most difficult to differentiate between the species of the *laborans* group from the Utah-Nevada areas. Without an anatomical study we conclude that the Mercury specimens should be considered as *laborans.*

1(1-1)C-3 *Steriphanus lubricans* Casey

Figure IX-H

Reference. Casey, Proc. Wash. Acad. Sci. IX, 1907, p. 345.

Morphological Characteristics. Body narrowly oval, convex, dark piceous, legs pale rufous; head deeply and closely punctate; sides converging and arcuate, prothorax two-thirds wider than long, basal angles obtuse and slightly blunt; punctures strong and fine, becoming dense and longitudinally confluent toward the sides; scutellum broadly rounded; elytra nearly one-half longer than wide, the sides parallel, punctures small but deep; abdomen sparsely punctulate medially. Length 5.1 to 6.2 mm; width 2.3 to 2.7 mm.

Plant Community Relationships. Four specimens were collected in a Grayia-Lycium community between March 29, 1960 and April 17, 1961, and one in the Atriplex community on August 22, 1960.

2(1-1)A-4 *Auchmobius subboreus* Blaisdell

Figures III; IV-D; XV-E

Reference. Blaisdell, Trans. Am. Ent. Soc., LX, 1934, p. 254, pls. IXII, IVII, and IVIII.

Morphological Characteristics. Length 9.1 to 10 mm; width 4.3 to 4.8 mm. Form oval, twice as long as wide; color black, labrum and palpi rufous, also legs and apical antennal segments; sides of epistoma straight and convergent; surface of head evenly punctate; mentum about one-half wider than long; maxillary palpi slender; antennae attaining the pronotal base. Pronotum twice as wide as long, widest at the middle; disk convex from side to side, rather evenly punctate, punctures as on the frons. Elytra a third longer than wide, about three times as long as the pronotum. Disk punctation rather dense, fine and not distinct, more evident laterally and apically; legs moderate in length and slender; metatarsi more than two-thirds as long as the tibia.

Plant Community Relationships. Twelve specimens were collected in Grayia-Lycium communities between March 31, 1960, and Aug-

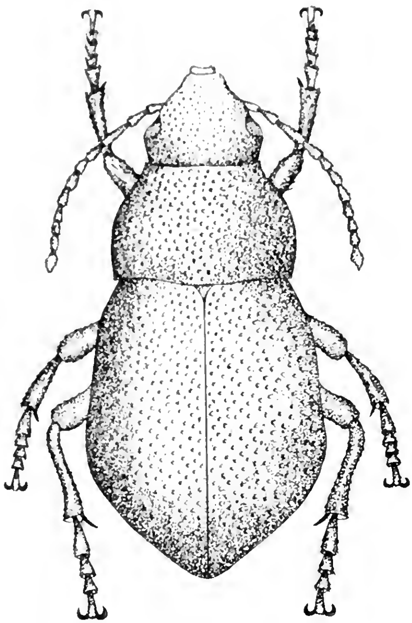

Figure III. *Auchmobius subboreus* Blaisdell.

ust 18, 1961. Eleven of the twelve were collected in 1960 in March, June, July and August. The other one was collected in August, 1961.

Twenty specimens were collected in Larrea-Franseria communities between July 9, 1960, and September 5, 1961, all but four in June, July, August and September, 1961. The other four were taken in July, 1960.

One was collected in a Pinyon-Juniper community on August 11, 1961.

Eight were collected in a Mixed community in the months of July, August and September, 1961.

3(1-1)A-5 *Chilometopon abnorme* (Horn)

Figures V-B, XV-G

References. Horn, Trans. Amer. Ent. Soc., V, 1874, p. 31. Casey, Proc. Wash. Acad. Sci., IX, 1907, p. 372.

Morphological Characteristics. Length 5.5 to 7 mm, form oblong; body slight, chestnut brown. Near coarsely and densely punctate; eyes large, prominent, and subentire. Last segment of antennae as long as the next two together. Prothorax broader than long, narrower at apex than base; coarsely and densely punctured especially toward the margins. Elytra wider than the pronotum, elongate-oval, sulci with finely muricate punctures. Legs moderately long and slender, the tarsal claws long and arcuate.

Plant Community Relationships. A total of 17 specimens was collected. They were found most abundantly in the Larrea-Franseria and Artemisia communities with one-fifteenth that amount in Gravia-Lycium and only a few found in the Lycium, Salsola and Mixed communities. They apparently were not present in the Atriplex-Kochia or Coleogyne.

Seasonal Activity. These beetles occurred from April to August with greatest abundance in July and August. They were first collected in April in the Mixed community. Activity in Gravia-Lycium began in June, whereas in other communities no activity occurred until July.

4(1-1)A-6 *Metopoloba bifossiceps Casey*

Figures IX-E; XIX-L

Reference. Casey, Proc. Wash. Acad. Sci., IX, 1907, p. 413.

Morphological Characteristics. Length 6 to 7 mm; elongate; fusiform; polished; subglabrous; deep brown to nearly black. Head coarsely, irregularly, and sparsely punctate; supraorbital carina prominent, last four antennal segments dilated and compressed. Pronotum trapezoidal; truncate apically and bisinuate basally; coarsely punctate. Elytra bisinuate basally; coarsely punctate; broadly arcuate at the sides; blunt humeri; slightly widest behind middle; sparse irregular punctures throughout; scutellum wider than long. Legs rather slender, not long compared to the length of the specimen.

Plant Community Relationships. A total of 15 specimens was collected. The greatest number occurred in the Gravia-Lycium, with about three-fifths in the Coleogyne. A small number was found in the Mixed community. No specimens were collected in Larrea-Franseria, Lycium, Atriplex-Kochia, Salsola or Pinyon-Juniper.

Seasonal Activity. This species was active only in July in the Coleogyne and Mixed communities, whereas in the Gravia-Lycium and disturbed Gravia-Lycium communities activity continued through August. The number of specimens collected in each of these two months was almost identical.

Comments. Only a few *M. bifossiceps* were collected in the can traps. Most of them were taken while feeding on *Atriplex confertifolia*

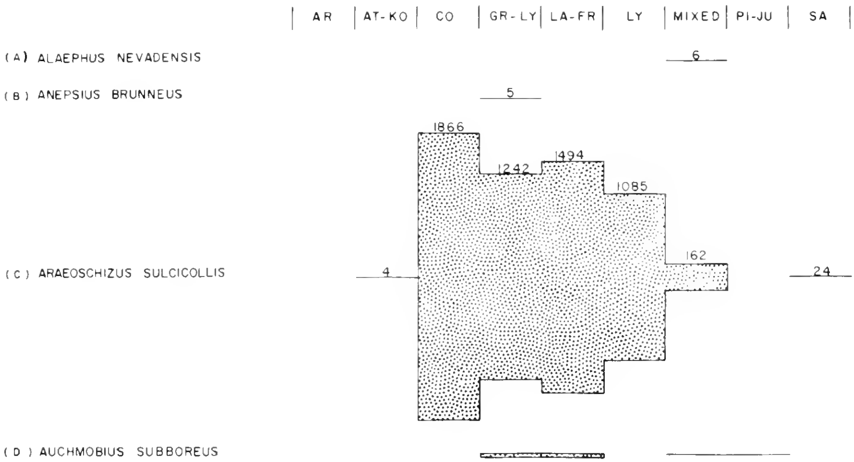

Figure IV. Number of specimens by species (A-D) found in nine plant communities. (In this and succeeding figure references to plant communities, the symbols stand for the following: AR = Artemisia, AT-KO = Atriplex-Kochia, CO = Coleogyne, GR-LY = Grayia-Lycium, LA-FR = Larrea-Franseria, LY = Lycium pallidum, MIXED = Miscellaneous, PI-JU = Pinyon-Juniper, SA = Salsola.)

during the middle of the day. A distinctive species.

5(1-1)A-7 *Triorophus laevis politus* Casey

Figures IX-I; XX-F

References. LeConte, Ann. Lyc. N. York, V, 1851, p. 141. Lacordaire, Gen. Col., V, 1859, p. 48. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, p. 259. Casey, Proc. Wash. Acad. Sci., IX, 1907, p. 435.

Morphological Characteristics. Length 7 to 8 mm; elongate in form; color varies from chestnut brown to nearly black, most commonly very deep reddish-black. Head almost as wide as pronotum; sparsely punctate; two supraorbital folds at each side; antennae stout, with the tenth segment as long as wide. Pronotum punctate with stiff yellow pubescence. Elytra elongate-oval; strongly inflated; punctures arranged in nine series. Legs long and slender; tarsi spinous beneath.

Plant Community Relationships. A total of 867 specimens was collected. The greatest number was found in the Grayia-Lycium, with about four-fifths of this number in Larrea-Franseria. They were about two-fifths as abundant in Lycium, whereas the Atriplex-Kochia and Mixed communities supported about one-fifth as many specimens as the disturbed Grayia-Lycium. In the Coleogyne community they were one-tenth as abundant, whereas in Salsola they were about one-thirtieth as abundant. The species was not found in Pinyon-Juniper or Artemisia.

Seasonal Activity. This species occurred in large numbers from April to October with single specimens collected in December, January and March. They were most abundant in May and declined steadily from then until October. In all communities beetles became active in April except in Salsola, where they were inactive until June. In Atriplex-Kochia they were active until June. Activity stopped in the Mixed community in August, whereas in Lycium and Coleogyne, activity continued through September. In the other communities they were active through October.

6(1-1)A-8 *Edrotes orbus* Casey

Figures VI-A; XVI-D

References. LeConte, Ann. Lyc. N. York, V, 1951, p. 140. Lacordaire, Gen. Col., V, 1859, p. 31. Casey, Proc. Wash. Acad. Sci. IX, 1907, p. 451. LaRivers, Ann. Ent. Soc. Amer., XL, No. 2, June, 1947, pp. 318-327.

Morphological Characteristics. Length 7 to 9 mm; form very round; convex; smooth; covered with short, erect, ashy-white hairs; varies from dull, grayish-black to highly polish, deep

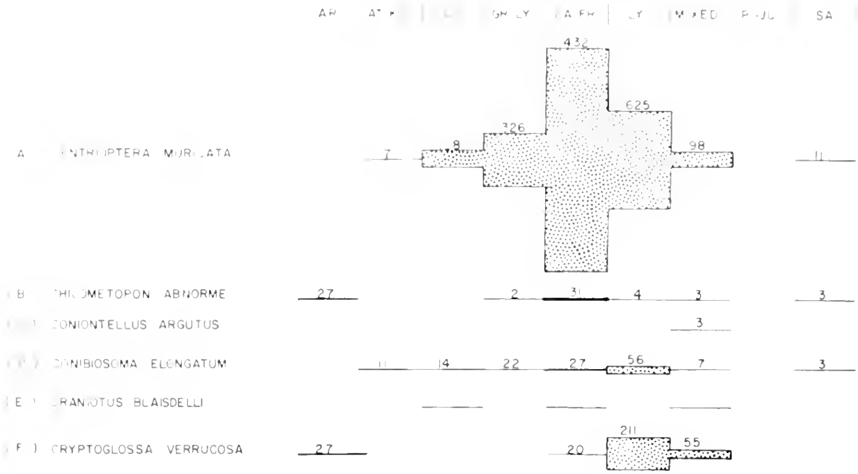

Figure V. Number of specimens by species (A-F) found in nine plant communities.

black. Head much narrower than the pronotum; the front very narrow. Pronotum four times wider than long; apical angle very acute and extended. well-separated tuberculate punctures. Elytra at least one and one-half times wider than pronotum; the punctures are minute and sparse; each puncture is behind a small abrupt tubercle. Legs fairly long; the hind femora reach the end of the abdomen.

Plant Community Relationships. A total of 2,005 specimens was collected. The greatest number occurred in Grayia-Lycium, whereas over half the number occurred in Salsola and one-third in Coleogyne. In Larrea-Franseria they were one-third as abundant, whereas Lycium supported only one-fifteenth as many. A few specimens were collected in the Atriplex-Kochia and Mixed communities, but none was present in Pinyon-Juniper and Artemisia.

Seasonal Activity. This species was active the year round in disturbed Grayia-Lycium, with the months of greatest activity being February, March, April and May. Months of least activity were June, July, November and December. Activity increased during the months of January, August, September and October. In the rest of the plant communities this species was active very little or not at all during May, June and July. The greatest period of activity in Larrea-Franseria and Lycium was during January and February, whereas in the Atriplex-Kochia, Salsola and Coleogyne communities the period of greatest activity was in March. In these latter three communities there was little or no activity during November and December.

7(1-1)A-9 *Araeoschizus sulcicollis* Horn

Figures IV-C; XV-D

References. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, p. 274; Trans. Amer. Ent. Soc., SVII, 1890, p. 341. Casey, Proc. Wash. Acad. Sci., IX, 1907, p. 488.

Morphological Characteristics. Length uniformly 4 mm; body form slender; elytra flattened; dark reddish-brown with light yellowish scales. Head large; much elongated; converging from antennal prominences to basal angle; eyes divided, elongate and narrow above, small round beneath; antennae long; very stout and compressed; the eleventh segment very small and almost hidden in the apex of the tenth; covered with yellowish scales. Pronotum very small; widest anteriorly; sulcate along the middle from apex to base; sides fringed with close-set, yellow scales; the sulci deeply punctate. Legs fairly short and stout with no spines.

Plant Community Relationships. A total of 2,664 specimens was collected. They were found in greatest number in the Coleogyne and were only slightly less abundant in the Larrea-Franseria and Grayia-Lycium communities. They were about three-fifths as abundant in Lycium as in Coleogyne. A few specimens were collected

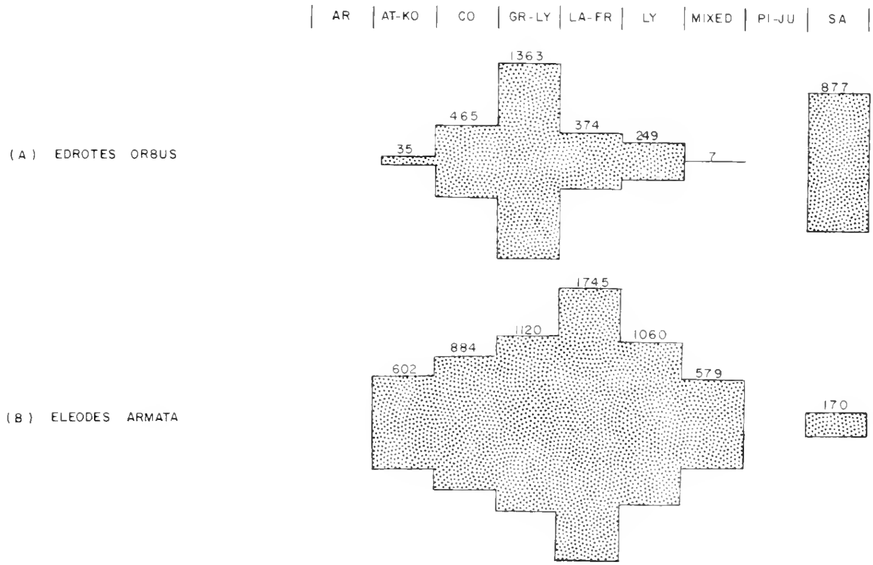

Figure VI. Number of specimens by species (A-B) found in nine plant communities.

in Atriplex-Kochia and Salsola, whereas none was found in the Pinyon-Juniper or Artemisia.

Seasonal Activity. This species occurred all the year round, being most abundant in September and April. The numbers declined in May, June and July, then increased in abundance through August to the population peak in September. Activity declined from October to February. In the disturbed Grayia-Lycium, Grayia-Lycium, and Mixed communities activity was evident every month of the year. In Coleogyne there was activity each month except December and February. Beetles were not active in the Larrea-Franseria community in January and February or in Lycium from December through March. In Salsola this species was taken in small numbers in May, June, September, October and November, whereas in Atriplex-Kochia it was collected only in July. It was not present in the Pinyon-Juniper.

8(1-1)A-10 *Anepsius brunneus* Casey

Figures IV-B; XV-B

Reference. Casey, Proc. Wash. Acad. Sci., IX, 1907, p. 506.

Morphological Characteristics. Length 4 to 4.5 mm; elongate; convex; reddish brown; shining. Head large; trapezoidal; strongly and closely asperato-punctate; eyes completely divided with the upper lobe large and elongate; antennae long and slender. Pronotum wider than long; the anterior angles acute and prominent; finely punctate. Elytra slightly wider than the prothorax; humeri obtuse and distinct; very finely punctate in series. Legs fairly short and slender.

Plant Community Relationships. A total of 39 specimens was collected. They were most abundant in disturbed Grayia-Lycium, and about one-seventh as abundant in Lycium and Grayia-Lycium. A few specimens were taken in the Salsola, Coleogyne and Mixed communities. They were not found in Larrea-Franseria, Atriplex-Kochia or Pinyon-Juniper.

Seasonal Activity. This species was active from March through November, and most abundant in May. Beetles were about one-fourth as abundant during March and June as in May, with very few specimens collected in April and July through November. In disturbed Grayia-Lycium they were collected from March through June, and September through November. In the Lycium community they occurred in July and August, whereas in Grayia-Lycium they were active in May and June. In Coleogyne there was activity during April, during May in Mixed, and July in Salsola.

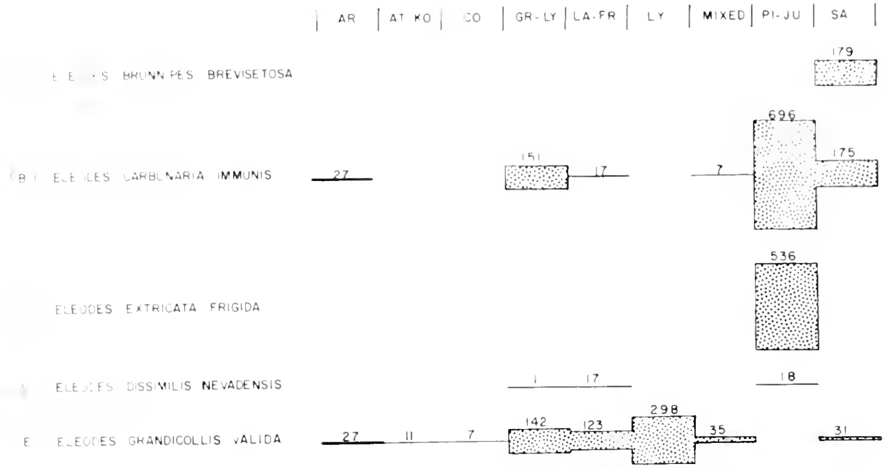

Figure VII. Number of specimens by species (A-E) found in nine plant communities.

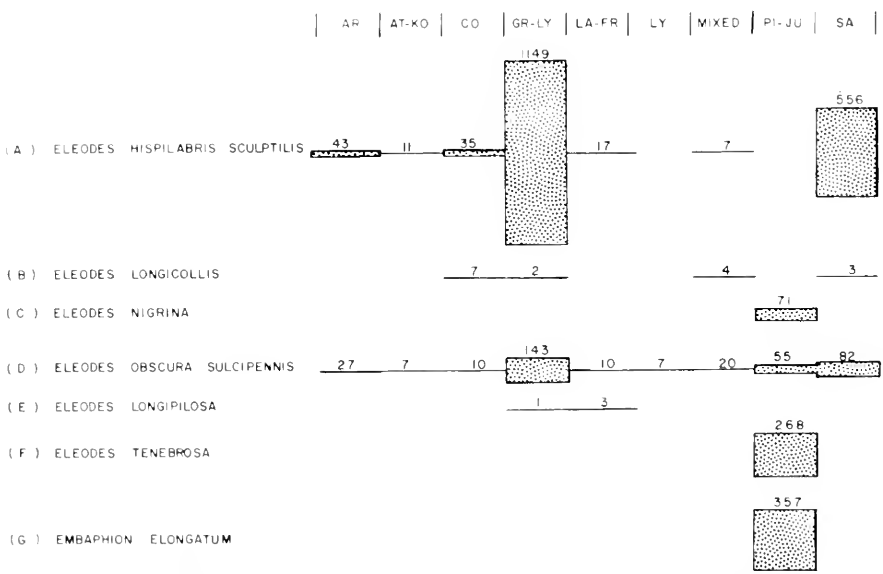

Figure VIII. Number of specimens by species (A-G) found in nine plant communities.

Comments. Although this genus was established by LeConte (1851), Casey (1892, 1907) named most of the species presently therein. Comparison of our series was made with specimens of *A. brunneus* Casey. This genus is in need of revision.

9(1-1)A-11 *Cryptoglossa verrucosa* LeConte

Figures V-F; XVI-C

References. LeConte, Ann. Lyc. N. York, V, 1851, p. 129. Lacordier, Gen. Col., 1859, p. 42. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, p. 280. Triplehorn, Coleopterist's Bull., Vol. 18, No. 2, pp. 43-52, 1964.

Morphological Characteristics. Length 17 to 21 mm; form elongate-oval; very heavy appearance, light bluish-gray to deep black. Head, anterior front coarsely punctate; coalescent; the vertex granulate; eyes emarginate; antennae short and flattened with the eleventh segment truncate and much smaller than the tenth. Pronotum very rough and tuberculate; a medial suture extends from the apex to the base; apical angle acute and extended. Elytra evenly arcuate from base to apex; nine rows of large, evenly-spaced tubercles traverse the full length; apex abruptly rounded. Legs long and stout; the tarsi covered with reddish-orange spines.

Plant Community Relationships. A total of 116 specimens was collected. The greatest number occurred in the Lycium community, with about one-fourth the number in Mixed, over one-tenth in Artemisia, and slightly fewer than one-tenth in Larrea-Franseria. They were not observed in Atriplex-Kochia, Grayia-Lycium, Salsola, Coleogyne, or Pinyon-Juniper.

Seasonal Activity. This species occurred from April to September, but was most abundant in August. One specimen was collected in November. Abundance was increased from May to June, declined slightly in July and then reached a peak in August. There was a large decline in September. In the Lycium and Mixed communities beetles were active from May to September, whereas in Larrea-Franseria activity was evident only during August and September.

9(1-1)B-12 *Centrioptera muricata* LeConte

Figures V-A; XV-F

References. LeConte, Ann. Lyc. N. York, V, 1951, p. 142. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, p. 279.

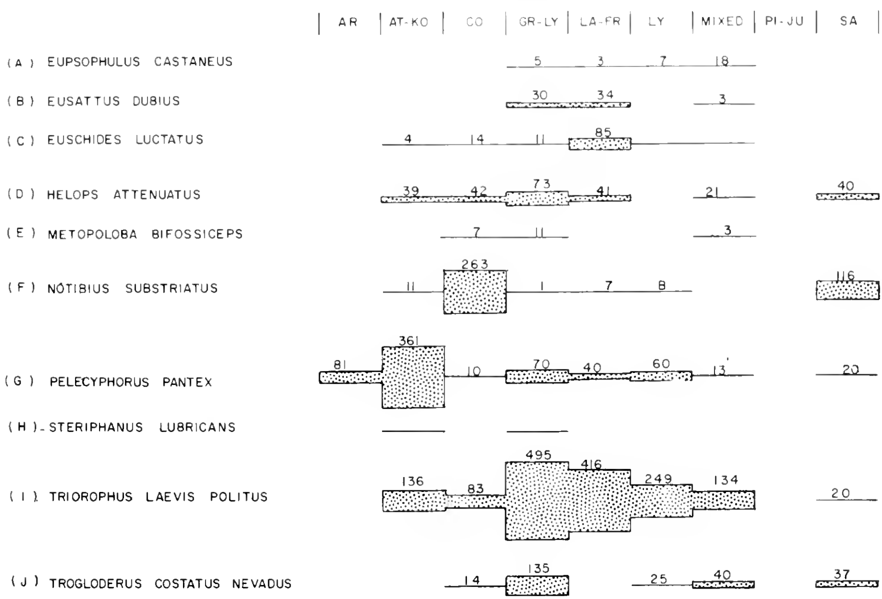

Figure IX. Number of specimens by species (A-J) found in nine plant communities.

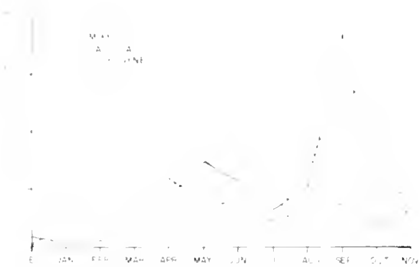

Figure X. Number of specimens seasonally in Mixed, Salsola, and Coleogyne communities.

Morphological Characteristics. Length 14 to 23 mm, form elongate; broadly rounded posteriorly, varying from dull gray to shining black. Head deeply and sparsely punctate; antennae moderate and stout, last segment oval and only slightly smaller than the tenth segment. Pronotum glabrous and shining, completely margined, deeply punctate laterally; punctures becoming very fine medially. Elytra elongate becoming broadly arcuate posteriorly; spiculae located along the lateral edges; becoming longer toward the apex. Legs moderately long and stout.

Plant Community Relationships. A total of 1,056 specimens was collected. The greatest number occurred in the Larrea-Franseria community, with about two-fifths the number in Lycium and one-fourth in Gravia-Lycium. The Coleogyne and Mixed communities supported about one-fourteenth as many beetles as Larrea-Franseria, whereas a few specimens were collected in Atriplex-Kochia and Salsola. They were not found in the Pinyon-Juniper or Artemisia communities.

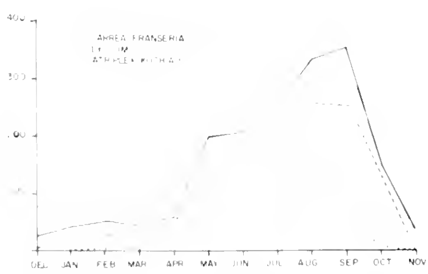

Figure XI. Number of specimens seasonally in Larrea-Franseria, Lycium, and Atriplex-Kochia communities.

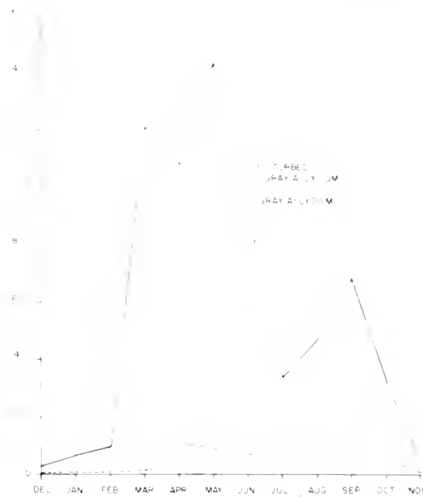

Figure XII. Number of specimens seasonally in disturbed Gravia-Lycium and Gravia-Lycium communities.

Seasonal Activity. This species was active from April through September, and was most abundant in June. From April to June, abundance of beetles increased, and from June to September, decreased. Beetles began activity in April in the Larrea-Franseria, Lycium, disturbed Gravia-Lycium, Salsola and Mixed communities. In all these except the Salsola community, activity continued until September. In Salsola the only other month in which they were active was June. In the Coleogyne community they were active from May to August, and in Atriplex-Kochia only in June.

1(1-2)A-13 *Pelecyphorus pantex* Casey

Figures IX-G; XIII; XX-B

References. Casey, Memoirs on the Coleoptera, III, 1912, p. 116. Tanner and Packham, Great Basin Nat., XXII, No. 4, 1962, p. 110.

Morphological Characteristics. Length 16 to 22 mm; form very ventricose; the anterior smaller than the posterior; deep black. Head not densely separately punctate; front somewhat dilated; last segment of antennae very small and partially surrounded by the tenth segment. Pronotum moderately convex; strongly granulate medially; edges slightly explanate with the sides unevenly scalloped. Elytra greatly inflated; surface granulate; the outer costa strong, the inner very fine to subobsolete. Legs fairly long

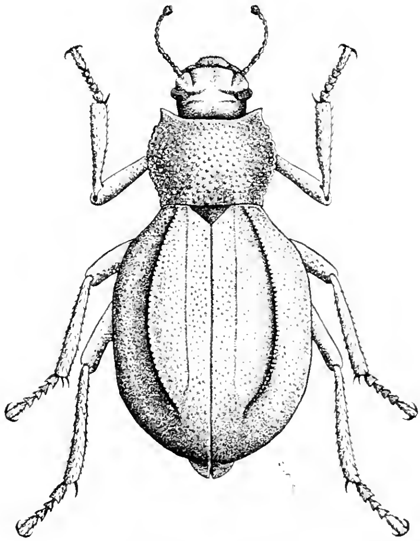

Figure XIII. *Pelecyphorus pantex* Casey.

and stout; the anterior tibia slightly dilated at the apex.

Plant Community Relationships. A total of 228 specimens was collected. The greatest number occurred in the Atriplex-Kochia community, with slightly over one-fifth the number in Artemisia, Grayia-Lycium and under one-fifth in Lycium. In Larrea-Franseria they were about one-ninth as abundant as in Atriplex-Kochia, whereas their abundance in the Salsola, Colegyne and Mixed communities was approximately one-twentieth. They were not found in Pinyon-Juniper.

Seasonal Activity. On March 31 in the disturbed Grayia-Lycium seven *P. pantex* were collected. No further activity was recorded until July. Except for this collection they occurred seasonally from July to October, being most abundant in August. Very few were collected in July, December and November, whereas they were slightly over one-third as abundant in September as in August. In the disturbed Grayia-Lycium they were active in March, July, August and September. Activity in Salsola occurred during July and August, whereas in Coleogyne they were active only in August. In the Atriplex-Kochia community they were active in August, September and November. In other communities where this species occurred they were active only in August and September.

1(1-2)B-14 *Pelecyphorus semilaevis* (Horn)

Figures XIV; XX-C

References. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, p. 284. Casey, Memoirs in the Coleo., III, 1912, p. 182. Tanner and Packham, Great Basin Nat., XXII, No. 4, 1962, p. 110.

Morphological Characteristics. Length 21 to 24 mm; form elongate-oval; narrowing from posterior to anterior, black. Head coarsely and sparsely punctate; front not dilated or only slightly so; eyes large and emarginate; third segment of antennae long; eleventh only slightly smaller than tenth. Pronotum coarsely, sparsely, and unevenly punctate; the sides are narrowly reflexed, moderately rounded and not scalloped. Elytra elongate-oval with distinct marginal costa; three straight, nearly parallel costa; the surface shining between the suture and first costa; the remainder opaque. Legs moderately long and stout; anterior tibia expanded apically into a spine.

Plant Community Relationships. A total of 31 specimens was collected. The greatest number occurred in the Atriplex-Kochia and the Grayia-Lycium communities and only two-fifths in disturbed Grayia-Lycium. Larrea-Franseria

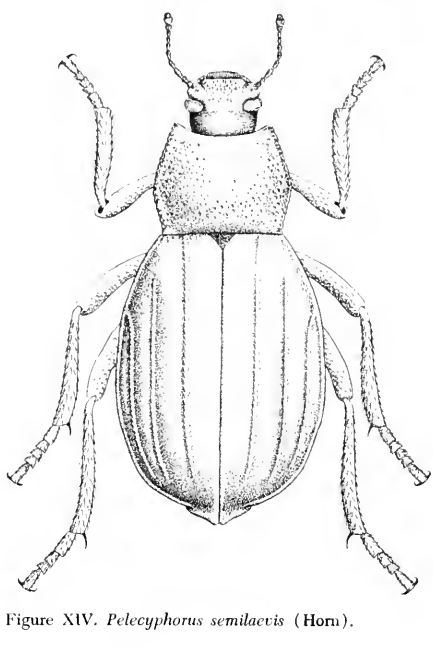

Figure XIV. *Pelecyphorus semilaevis* (Horn).

and Lycium supported about one-fourth the population of the Atriplex-Kochia, whereas the Coleogyne and Mixed communities supported only about one-eighth. They were not found in Salsola, Pinyon-Juniper or Artemisia.

Seasonal Activity. *P. semilaevis* were collected only from July through September. They were most abundant in August. In all communities in which they were found they were active during this month. In Lycium and disturbed Gravia-Lycium they were active in July. Activity in all communities ceased in September.

I(1-2)C-15 *Euschides luctatus* (Horn)

Figures IX-C, XIX-J

References. Horn, Trans. of the Amer. Phil. Soc., XIV, 1870, p. 286. Casey, Memoirs on the Col., III, 1912, p. 155.

Morphological Characteristics. Length 12.5 to 17.5 mm; elongate oval, black. Head very sparsely punctate, eyes large and slightly protruding, second segment of antennae very short. Pronotum widely and acutely margined; sparsely punctate medially, more coarsely and densely punctate at margins. Elytra elongate-oval; without marginal costa or ridge; surface weakly granulate. Legs moderate and slender.

Plant Community Relationships. A total of 51 specimens was collected. The greatest number occurred in Larrea-Franseria, with about one-seventh the number in the Coleogyne and Mixed communities. A few specimens were found in Gravia-Lycium, Atriplex-Kochia and Lycium, whereas none was found in Salsola, Pinyon-Juniper or Artemisia.

Seasonal Activity. This species was active from September to April. Beetles were most abundant during October, November, December and February. Activity was noted in disturbed Gravia-Lycium from September to January. In the Mixed community there was activity from October to February, whereas in Coleogyne beetles were active only during October and November. In Larrea-Franseria they were active from November to April.

I(1-2)D-16 *Trichiasida acerba* (Horn)

Figure XX-E

References. Horn, Trans. Amer. Ent. Soc., VII, 1878, pp. 51-60. Casey, Memoirs on the Coleoptera, III, 1912, p. 176.

Morphological Characteristics. Length 11 to 14 mm; form elongate-oval; brownish elsewhere. Head sparsely punctate; antennae short, reach-

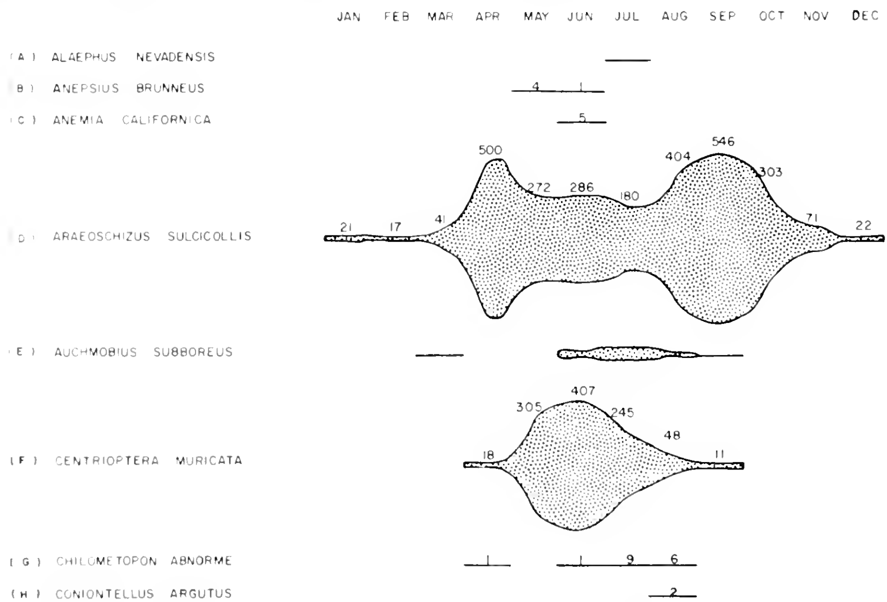

Figure XV. Number of specimens seasonally collected in all the biotic communities.

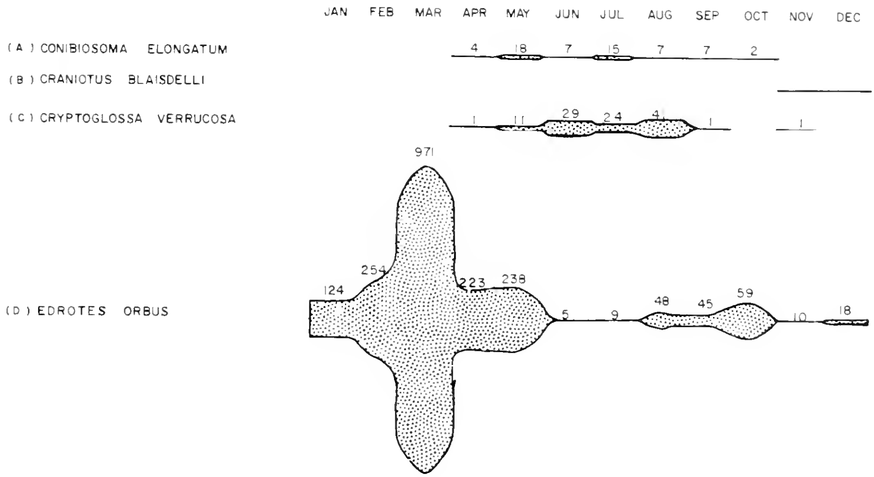

Figure XVI. Number of specimens seasonally collected in all the biotic communities.

ing slightly over half-way back on the pronotum. Pronotum densely punctate, margin feebly reflexed. Elytra oblong-oval, very finely punctate. Legs slender, anterior tibia set with small teeth or notches on the outer margin.

Plant Community Associations. A total of 71 specimens was collected. They were found in greatest numbers in the Larrea-Franseria community, with one-third the number in Salsola, and one-fourth in Lycium, Grayia-Lycium and Mixed.This species was not found in Atriplex-Kochia, Grayia-Lycium, Coleogyne, Pinyon-Juniper or Artemisia.

Seasonal Activity. This species was active from October to April. Activity was high during all these months except April. Greatest activity was during February and March. This species was active in the disturbed Grayia-Lycium, Salsola, and Mixed communities from October to March. Activity of this species started in both Larrea-Franseria and Lycium in November, but ceased in Lycium during February and continued in Larrea-Franseria until April.

2(1-2)A-17 *Craniotus blaisdelli* Tanner

Figures V-E; XVI-B; XVII

Reference. Great Basin Nat., Vol. 23, Nos. 3-4, 1963, pp. 167-170.

Morphological Characteristics. Length 10 to 13 mm; width 5 to 6 mm; form robust, two times as long as wide. Color deep black, lustre dull to slightly shining.

Head small, projections at the sides of the head anterior to the eyes extend beyond one-third the width of the head; frons depressed between the projections and clypeal area; clypeus slightly emarginate; epistoma punctures discrete, small, irregular, each bearing a short black seta. Eyes transverse, not emarginate, larger dorsally. Antennae slender, third joint as long as the fourth and fifth combined, in length not extending to the pronotal base; the eleventh segment small, attached to apex of tenth.

Pronotum about one-sixth wider than long, sides without margins, disk convex, anterior angles acute, surface with irregularly placed papilliform structure, each bearing a decumbent brownish-colored seta. Base broadly truncate, scutellum elongate.

Elytra one-third longer than wide, base equal to that of the pronotum; humeri obsolete, sides broadly arcuate, disk moderately convex; arcuately precipitous at apex; surface devoid of striae; small punctures from which arise short stiff black setae; lustre dull to more or less shining, connate, the suture, however, is distinct. Epipleurae without a trace of a suture.

Legs long, especially the tibia of the metathoracic legs; coxae closed and widely separated. First and second abdominal sternites about equal in width, punctured and with black short erect setae.

Genitalia of the female, Figure V-A-B, of the elongate type, rather heavily sclerotized valvifer; coxite small, black, with obscure stylus; ninth

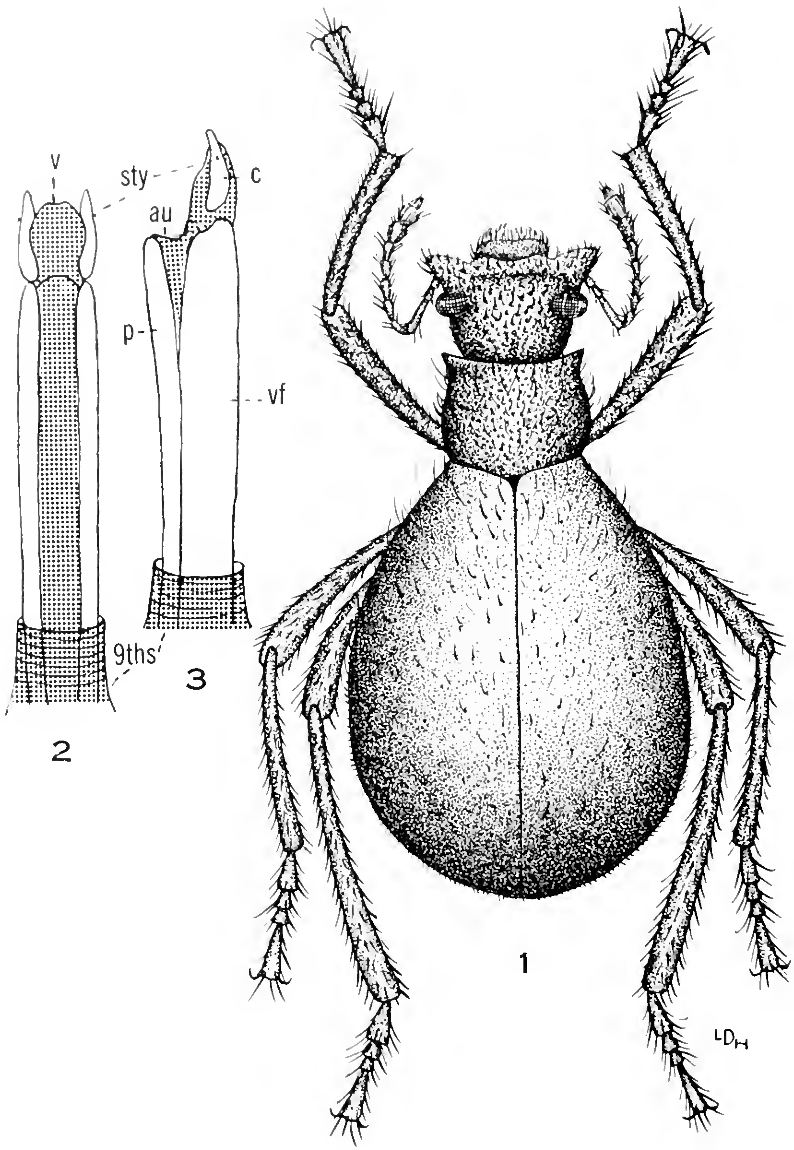

Figure XVII. *Craniotus blaisdelli* Tanner. (1) Dorsal view of female; (2) ventral view of genitalia; (3) lateral view of genitalia: v=vulva; sty=stylus; c=coxite; au=anus; p=proctiger; vf=valvifer; 9ths=9th sternite.

segment membranous, acting as a sheath for the retracted genital organ. The female genitalia of *Pelecyphorus semilaevis* is an elongate type similar in structure to *C. blaisdelli.*

Plant Community Relationship. A single specimen was collected in a Coleogyne community on November 28, 1960, one in a Larrea-Franseria community on November 9, 1961, and one in a Mixed community on December 8, 1961.

1(1-3)A-18 *Trogloderus costatus nevadus* LaRivers

Figures IX-J; XX-G

References. LaRivers, Ann. of Ent. Soc. of Amer., XXXV, 1942, pp. 435-440. Tanner, Great Basin Nat., XXI, No. 3, 1961, p. 76.

Morphological Characteristics. Length 8 to 15 mm; elongate; opaque; reddish-brown to purple black; elytral costae acutely elevated. Head rough and tuberculate; antennae short and stout. Pronotum widest at the middle; evenly arcuate from apex to base with lateral margin serrate anteriorly and roughened posteriorly; median foveae faint to quite pronounced; densely punctate and coalescing. The elytral base narrower than opposed pronotum; sutural costa weaker than discal and humeral costa; sulci weakly and irregularly punctate. Legs rather stout; femora punctate; tibiae muricate; first joint of anterior tarsi with distinct process beneath.

Plant Community Relationships. A total of 188 specimens was collected. The greatest numbers occurred in Grayia-Lycium, with one-fourth of this number in Salsola and one-third in Mixed. In Lycium they were one-fifth as abundant, and in Coleogyne they were one-ninth as abundant. They were not found in Larrea-Franseria, Atriplex-Kochia and Pinyon-Juniper communities.

Seasonal Activity. This species was active from March through October, with the greatest numbers collected in August. From March through June there was a steady increase in collections. In July a slight decrease occurred. In August the number collected more than tripled. September collections returned to about the same rate as was observed in July. In October one specimen was found. In Salsola and Mixed their activity began in June and ended in September for Mixed, but continued into October in Salsola. In Lycium they were active during July, August and September; in Grayia-Lycium they were active in July and September. In Coleogyne they were active only in August.

Comments. This beetle was first described by LaRivers (1942) as a new species, *T. nevadus.* Tanner (1961) reduced it to a subspecies of LeConte's *T. costatus* (1879). Along with Dr. LaRiver's description were the observations that they were abundant in sand dunes. Many of our specimens, collected in Mixed community, were collected from sand dunes. In other communities they were most abundant where the soil was sandy.

1(1-3)A-19 *Embaphion elongatum* Horn

Figures VIII-G; XIX-H

References. Horn, Trans. Amer. Phil. Soc., XII, New Series, 1870, pp. 321, 323. Blaisdell, Bull. 63, U. S. Nat. Mus., 1909, Mon., p. 454. Tanner, Great Basin Nat., XXI, No. 3, 1961, p. 76.

Morphological Characteristics. Length 12 to 16 mm; elongate; nearly three times longer than wide; surface dull; acute elytral margin reaching to apex. Head small, mentum trilobed, middle lobe broad, rounded in front, lateral lobes small; eyes distinctly emarginate; antennae long, reaching beyond base of pronotum. Pronotum with acute reflexed margin; apical angles narrowly rounded, attaining the eyes. Elytra elongate; margin acute, evenly reflexed and reaches the apex; surface sculptured with fine, irregularly and sparsely placed punctures; each puncture bears a minute decurved seta. Legs long and slender.

Plant Community Relationship. A total of 20 specimens was collected. They were found only in Pinyon-Juniper.

Seasonal Activity. They were active only in August and July with the greatest abundance being in August.

1(1-3)C-20 *Eleodes carbonaria immunis* LeConte

Figures VII-B; XVIII-C

Reference. LeConte, Proc. Acad. Nat. Sci. Philadelphia, 1858, p. 186.

Morphological Characteristics. Length 12 to 18 mm; oblong-ovate to ovate; more or less shining and smooth. Head finely punctate. Pronotum widest at, or just in front of, the middle; finely and sparsely punctate; apical and basal angles obtuse. Elytra finely and diffusely punctate; a serial arrangement usually evident.

Plant Community Associations. A total of 264 specimens was collected. The highest occur-

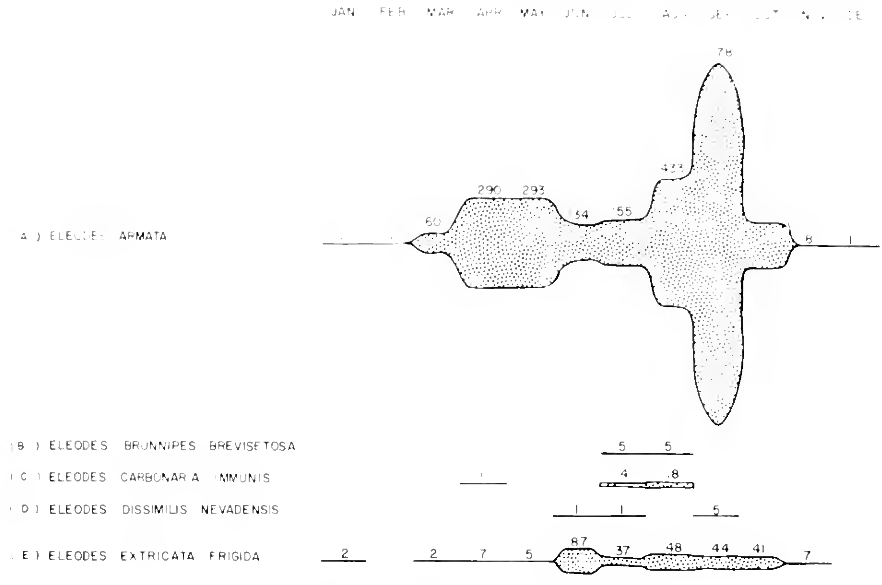

Figure XVIII. Number of specimens seasonally collected in all the biotic communities.

rence was in Pinyon-Juniper, with about one-fifth that number in Salsola and Grayia-Lycium. There were few specimens found in Artemisia, Kochia, Coleogyne and Lycium. *E. carbonaria* was active from March to November at lower elevations; on Rainier Mesa activity lasted only during July and August. Beetles were most abundant at the lower elevations in June whereas the higher altitude population peak was August. Only a few specimens were collected in March, April, January and May. Activity declined in July and August and then increased again during September and October. In the disturbed Grayia-Lycium and Salsola it was active from March through October.

1(1-3)C-21 *Eleodes obscura sulcipennis* Mannerheim

Figures VIII-D, XIX-E

References. Mannerheim, Bull. Moscow, XVI, 1843, II, p. 266; Mag. Zoo., XIII, 1843, p. 128. LeConte, Proc. Acad. Phil., 1858, p. 182; Entomological Report, 1857, p. 50. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, p. 306. Blaisdell, Bull. 63, U. S.Nat. Mus., Mono., 1909, pp. 190, 194; Pan-Pac. Ent., XI, 1925, pp. 77-80. Tanner, Great Basin Nat., XXI, 1961, pp. 55-78.

Morphological Characteristics. Length 24 to 33 mm; oblong; strongly sulcate and shining. Head half as long as pronotum; antennae long, fairly broad, not reaching base of pronotum. Pronotum broadest forward of the middle; lightly punctate, completely margined. Costa of the elytra distantly spaced, muricate punctures, the sulci with closely spaced muricate punctures. Legs long and heavy.

Plant Community Relationships. A total of 210 specimens was collected. They were found in greatest numbers in disturbed Grayia-Lycium, with about two-fifths the number in the Salsola and three-tenths as many in the Pinyon-Juniper communities. The populations in the Grayia-Lycium and Mixed communities were about one-tenth as large as in disturbed Grayia-Lycium. Only a few specimens were found in Larrea-Franseria, Lycium, Atriplex-Kochia, and Coleogyne.

Seasonal Activity. This species was active from March through October, and was most abundant during April and August. In May, June and March the populations were about half as large as in April and August. Very few were collected in October, September and July. In the disturbed Grayia-Lycium, Salsola, Grayia-

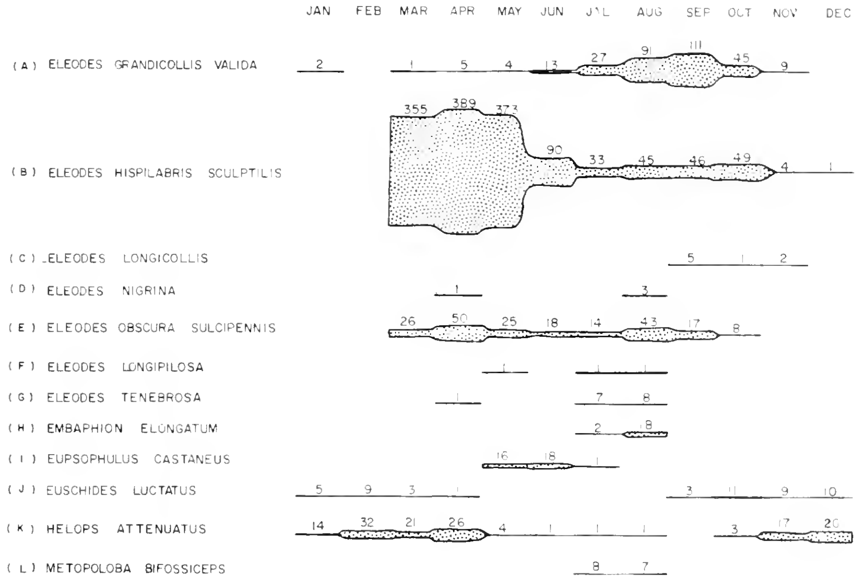

Figure XIX. Number of specimens seasonally collected in all the biotic communities.

Lycium and Mixed communities this species became active in March. Activity in disturbed Grayia-Lycium and Salsola continued until October. In Grayia-Lycium and Mixed the activity stopped in May, then resumed again in August, September and October. Activity in Larrea-Franseria, Lycium, and Atriplex-Kochia was from July through September. In the Coleogyne community beetles were active only in August.

Comments. Members of this species were frequently attracted to rolled oats used as bait for trapping rodents.

1(1-3)C-22 *Eleodes grandicollis valida* Boheman
Figures I; II; VII-E; XIX-A

References. Boheman, Kongliga Svenska Fregatten Dugenies Resa, etc., Coleoptera, Stockholm, 1858-1859, p. 90. Blaisdell, Bull. 63, U. S. Nat. Mus., Mono., 1909, p. 208. Tanner, Great Basin Nat, XXI, No. 3, 1961, p. 72.

Morphological Characteristics. Length 25 to 30 mm; large and robust; oblong oval; black and shining. Head wider than long; antennae rather short and stout, reaching three-fourths of the way to the base of the pronotum. Pronotum widest at the middle; finely, evenly and sparsely punctate. Elytra smooth and shining; oval and robust; punctures fine and arranged in series. Legs moderate in length and very stout.

Plant Community Relationships. A total of 308 specimens was collected. They were most abundant in the Lycium community. They were about two-fifths as abundant in the Grayia-Lycium and slightly less than one-third as abundant in the Larrea-Franseria. In the Salsola, Artemisia and Mixed communities they were one-tenth as abundant. A few specimens were found in Atriplex-Kochia and Coleogyne. None was present in the Pinyon-Juniper.

Seasonal Activity. This species occurred from March through November with the exception of two specimens collected in January. The greatest occurrence was in August and November. Specimens were collected from Grayia-Lycium in January, and then from March to November. Specimens were collected from the Lycium community in January and then from April to November. This species became active in June in Mixed, Salsola and Larrea-Franseria, and November in Mixed. Grayia-Lycium had activity from July through September, the Atriplex-Kochia in August and September, whereas in Coleogyne communities there was activity only in November.

1(1-3)C-23 *Eleodes hispilabris sculptilis* Blaisdell
Figures VIII-A, XIX-B

References. Blaisdell, Bull. 63, U.S. Nat. Mus., Mono., 1909, p. 220. Tanner, Great Basin Nat., XXI, No. 3, 1961, p. 72.

Morphological Characteristics. Length 18 to 37 mm, elongate ovate; somewhat shining; somewhat convex and sulcate, color black. Head wider than long, antennae long, reaching to base of pronotum; outer four segments compressed and dilated. Pronotum finely, sparsely, and evenly punctate, apical angles acute and everted; basal angles obtuse. Elytra sulcate; less than twice as long as wide; sulci have a series of evenly, closely placed, small separate punctures; costa convex, smooth, and shining, each with a single irregular series of distantly placed punctures. Legs slender, posterior femora reaching fifth segment of abdomen.

Plant Community Relationships. A total of 1,385 specimens was collected. The greatest numbers occurred in the Gravia-Lycium community, with three-eights of this number in Salsola. In Coleogyne and Artemisia they were only one-fiftieth as abundant as in disturbed Gravia-Lycium. A few specimens were taken from Larrea-Franseria, Atriplex-Kochia and Mixed communities. None was found in the Pinyon-Juniper or Lycium.

Seasonal Activity. This species was active from March to December, with the peak of abundance in March, April and May. The numbers collected dropped off rapidly in June and remained low from July to October. In November only four specimens were collected and in December only one. In disturbed Gravia-Lycium, Gravia-Lycium, Salsola, Coleogyne and Larrea-Franseria communities activity began in March. In Salsola activity was recorded until December whereas the disturbed Gravia-Lycium had activity until November and Gravia-Lycium only until May. Activity in Coleogyne stopped in April for four months then commenced again in September and October. In Larrea-Franseria there was no activity from the end of March until August, when slight activity was recorded. In Atriplex-Kochia community this species was found active during April and August, whereas Mixed communities had activity only in August and September.

1(1-3)C-24 *Eleodes longipilosa* Horn
Figures VIII-E; XIX-F

References. Horn, Trans. Amer. Ent. Soc., XVIII, 1891, p. 42. Blaisdell, Bull. 63, U. S. Nat. Mus., Mono., 1909, pp. 212, 230. Tanner, Great Basin Nat., XXI, No. 3, 1961, p. 72.

Morphological Characteristics. Length 25 to 28 mm; elongate-oval; moderately shining; with a tail-like extension; surface sparsely covered

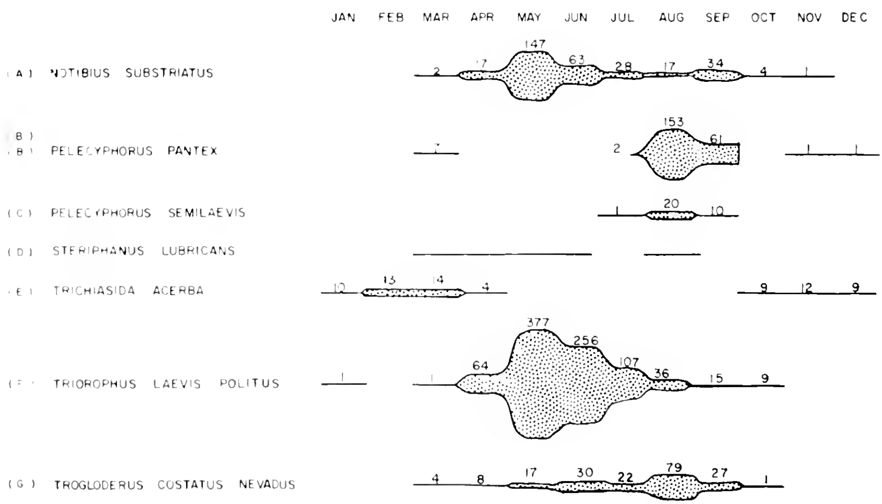

Figure XX. Number of specimens seasonally collected in all the biotic communities.

with long black hairs. Head irregularly punctate; hairs are long and flying; antennae moderately long and thick; slightly dilated on the last four segments; covered with rather long, stiff hairs. Pronotum widest slightly in advance of the middle; irregularly and sparsely punctate; long flowing hairs on the lateral edges. Elytra attenuated posteriorly in a tail-like extension; vaguely sulcate; punctures slightly muricate near suture, becoming strongly muricate laterally; both long flying hairs and short stout hairs are present. Legs moderately long and thick with long flying hairs.

Plant Community Relationships. A total of eight specimens was collected in the Grayia-Lycium, Coleogyne, Salsola, and Mixed communities.

Seasonal Activity. The three collections of this species were made in September, October and November. The September collection was in Mixed, Salsola and Coleogyne, October in Coleogyne, and November in Grayia-Lycium.

Comments. One of the eight specimens was collected in a can trap. Two others were taken by hand. Both were collected at dusk, one feeding on *Atriplex confertifolia* and the other emerging from a rodent burrow.

1(1-3)C-25 *Eleodes armata* LeConte

Figures VI-B; XVIII-A

References. LeConte, Ann. Lyc. N. York, V, 1851, p. 134; Arcan. Nat., 1859, p. 125; Proc. Acad. Phil., 1858, p. 181. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, pp. 303, 310. Blaisdell, Bul. 63, U. S. Nat. Mus., Mono., 1909, p. 259. Tanner, Great Basin Nat., XXI, No. 3, 1961, p. 72.

Morphological Characteristics. Length variable 24 to 33 mm; elongate; shining. Head moderately convex; more or less impressed laterally; frequently frons broadly and transversely impressed with the vertex strongly convex; antennae does not reach the base of the pronotum. Pronotum widest in advance of middle; sparsely and evenly punctulate; apical angles finely punctate; punctures in unimpressed series. Legs moderately long; hind femur reaching the fifth abdominal segment; femora with strong teeth.

Plant Community Relationships. A total of 2,878 specimens was collected. The greatest numbers occurred in the Larrea-Franseria community, with about seven-tenths of this number in Grayia-Lycium and four-sevenths in Lycium. In Coleogyne they were about one-half as abundant, and one-third as abundant in Atriplex-Kochia and Mixed communities. They were only one-tenth as abundant in Salsola, and were not found in Pinyon-Juniper or Artemisia.

Seasonal Activity. These beetles were active all year long. They were far more abundant in September than at any other time. During November, December, January and February small numbers were collected. In March an increase occurred and a low peak was reached in April and May. In June and July the numbers collected decreased again. The amount increased abruptly in August and continued to increase to the high peak in September; in October collections decreased more abruptly. In the disturbed Grayia-Lycium this species was active in January. In February they were not collected, but were from March to November. In Salsola their activity started in February and continued through October. In Larrea-Franseria, Lycium and Mixed communities this species' activity started in March and ended in November, except in Lycium where activity continued into December. In Atriplex-Kochia, Grayia-Lycium and Coleogyne communities they were active in April and continued through October, except for Coleogyne in which they were active in November.

1(1-3)C-26 *Eleodes armata pumila* Blaisdell

Reference. Blaisdell, Trans. Am. Ento. Soc., LIX, 1933, pp. 191-210.

Morphological Characteristics. Length 18.0 to 20.0 mm; width 6.0 to 8.1 mm. Color black, punctation fine and very sparse, except on head, where the punctures are large, rather closely set, and feebly muricate.

Head as long as wide. Epistoma truncate, frons anterially punctate. Labrum slightly convex, with an emargination at the apex. Antennae slender, in length attaining the pronotal base, third segment four times as long as the second. Pronotum wider than long, apex truncate and emarginate between the prominent apical angles; base slightly arcuate, angles obtuse; disk convex.

Elytra subcylindrical convex; base about equal to that of the pronotum; humeral angles obtuse; disk rounded from side to side; punctation fine, close in strial series, interval space with irregular sparse punctures. Legs slender, moderate in length. Femoral teeth small and acute.

Plant Community Relationships. A total of thirty specimens was collected in the Grayia-Lycium and Lycium communities.

Seasonal Activity. These beetles were active from July until October. They were far more abundant in August and September. A few specimens were taken in November. They were associated with *armata*.

Comments. *Pumila* may be rather readily separated from *armata* by their smaller size, about one-half the size of *armata*; the shape of the pronotum, the very small punctures on the prothorax and elytra, and the smaller legs and femoral teeth, which are acute.

1(1-3)C-27 *Eleodes nigrina* LeConte
Figure VIII-C

References. LeConte, Proc. Acad. Phil., 1858, p. 186. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, pp. 303-313. Blaisdell, Bull. 63, U. S. Nat. Mus., Mono., 1909, p. 393. Tanner, Great Basin Nat., XXI, No. 3, 1961, p. 75.

Morphological Characteristics. Length 27 to 29 mm; elongated oblong-ovate; over three times longer than wide. Head scarcely, coarsely, irregularly, and densely punctured on the front; base irregularly granulated. Pronotum widest in front of the middle; surface finely, densely, and irregularly punctate becoming granulate laterally. Elytra punctate, arranged without evident order on the dorsum, muricato-granulate laterally and on apex. Legs moderate in stoutness and length.

Plant Community Relationship. A total of four specimens was collected. They were present only in the Pinyon-Juniper community.

Seasonal Activity. Members of this species were active in April and again in August. They were most abundant in August.

1(1-3)C-28 *Eleodes dissimilis nevadensis* Blaisdell
Figures VII-D; XVIII-D

References. Blaisdell, Bull. 63, U. S. Nat. Mus., Mono., 1909, pp. 393-402. Tanner, Great Basin Nat., XXI, No. 3. 1961, p. 75.

Morphological Characteristics. Length 10 to 13 mm; cylindrical tapering at the posterior end; antennae, tibia, and tarsi with rusty reddish-brown setae and spinules; ventral surface pubescent. Head finely punctate, punctures denser at the periphery, each with a short reclining seta, antennae long and slender. Pronotum widest slightly in advance of the middle; evenly and not densely punctate. Elytra elongate, oval and smooth, slightly wider than pronotum; striao-punctate; serial punctures small. Legs slender and somewhat long.

Plant Community Relationships. A total of 7 specimens was collected. They were about equally abundant in the Pinyon-Juniper and Larrea-Franseria communities and about one-fifteenth as abundant in disturbed Grayia-Lycium. They were not found in any of the other communities of the test site.

Seasonal Activity. These beetles were active in June, July and September. They were most abundant in September. They were active in June in disturbed Grayia-Lycium, July in the Pinyon-Juniper, and September in Larrea-Franseria.

1(1-3)C-29 *Eleodes longicollis* LeConte
Figure VIII-B

References. LeConte, Ann. Lyc. N. York, V, 1851, p. 134; Proc. Acad. Phil., 1858, p. 181. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, pp. 303-311. Blaisdell, Bull. 63, U. S. Nat. Mus., Mono., 1909, pp. 411, 425. Tanner, Great Basin Nat., XXI, No. 3, 1961, p. 75.

Morphological Characteristics. Length 24 to 32.5 mm; elongate to elongate-fusiform; black, smooth, and shining. Head finely and quite evenly punctate; eyes reniform; antennae moderately stout; reaches the base of pronotum; segments 9 to 11 ovate. Pronotum slightly wider than long; very finely margined; evenly arcuate; very finely and sparsely punctate. Elytra elongate; equal in width to the contiguous pronotum; finely, irregularly and evenly punctate; never asperate. Legs moderately long.

Plant Community Relationships. A total of 8 specimens was collected. The largest numbers occurred in the Coleogyne community, with three-fifths of the number in the Mixed and two-fifths in Salsola. They were not found in Larrea-Franseria, Lycium, Atriplex-Kochia, Pinyon-Juniper or Artemisia.

Seasonal Activity. They were active during September, October and November, with greatest abundance being in September. They were active only in September in the Salsola and Mixed and were active in September and October in Coleogyne. In disturbed Grayia-Lycium they were active only in November.

1(1-3)C-30 *Eleodes tenebrosa* Horn
Figure VIII-F

References. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, pp. 304, 316. Blaisdell,

Bull. 63, U. S. Nat. Mus., Mono., 1909, pp. 311, 326. Tanner, Great Basin Nat., XXI, No. 3, p. 73.

Morphological Characteristics. Length 13 to 16.5 mm; oblong-oval; elytral sculpturing consisting of very small shining tubercles arising from a very opaque base. Head densely punctate laterally and on epistoma; base tuberculate; antennae moderate in length and slightly robust. Pronotum densely punctate in the center and granulate at the sides. Elytra slightly wider than pronotum, sides evenly and not strongly arcuate; densely and irregularly covered with small, rounded shining tubercles. Legs moderate, anterior tarsi dissimilar in the sexes, middle tarsi are similar.

Plant Community Relationship. A total of 16 specimens was collected. The only community in which they were found was the Pinyon-Juniper.

Seasonal Activity. Members of this species were active during the month of April, and then no further activity was recorded until July and August. They were equally abundant during the last two months. No further activity was found after August.

1(1-3)C-31 *Eleodes brunnipes brevisetosa* Blaisdell

Figure VII-A

References. Blaisdell, Ent. News, XXIX, 1918, p. 162. Tanner, Great Basin Nat., Vol. XXI, No. 3, p. 75.

Morphological Characteristics. Length 12 to 13 mm; oblong-ovate; very densely and finely sculptured. Head two-thirds as wide as the pronotum, coarsely and densely punctate; antenna longer than the head and pronotum. Pronotum one-fourth wider than long; very deeply, coarsely, and confluently punctate; feebly arcuate to apex and broadly sinuate to base. Elytra nearly a third wider than the base of the pronotum; abruptly and obtusely rounded behind when viewed vertically; surface densely asperate, with the summits of the granules shining, each bearing a short seta. Legs moderate in length.

Plant Community Relationship. A total of 10 specimens was collected. They were found only in the Pinyon-Juniper community.

Seasonal Activity. This species was active only in July and August, and was equally abundant during these months.

Comments. When Blaisdell (1918) first described *E. brunnipes*, he called it a variety of *Eleodes pimelioides* Mannerheim. Tanner (1961) raised *E. brunnipes* to a specific level and placed *brevisetosa* Blaisdell as a subspecies of that species.

1(1-3)C-32 *Eleodes extricata frigida* LaRivers

Figures VII-C; XVIII-E

Reference. LaRivers, Journ. Ent. and Zoo., Vol. 35, No. 4, 1943, pp. 54-58.

Morphological Characteristics. Length 13 to 21 mm; elongate; oblong-ovate to ovate; sparsely sculptured. Head deeply punctate anteriorly, becoming granulate posteriorly; antennae moderately long and stout, reaching to the base of the pronotum. Pronotum finely and unevenly punctate. Elytra moderately convex, with the sides broadly rounded; densely sculptured with small muricate granules, shiny at their summit. Legs moderately long and slender, anterior femora with acute spines.

Plant Community Relationship. A total of 30 specimens was collected. This species was found only in the Pinyon-Juniper community.

Seasonal Activity. A single specimen was taken in April. No others were found until July and August when the population appeared to be equal during these two months. There was no activity observed after August.

1(1-4)A-33 *Sphaeriontis dilatata* (LeConte)

Reference. Casey, Proc. Wash. Acad. Sci., X, 1908, pp. 56, 59.

Morphological Characteristics. Length 10 to 11 mm; elongate-oval gradually pointed behind; deep black in color. Head small; front greatly dilated and deeply emarginate at the apex; (antennae missing on all the specimens collected). Pronotum very sparsely and finely punctate; base bisinuate; basal angles acute and reticulate. Elytra slightly longer than wide; very feebly subcostulate with weak muricate punctures in sulca. Legs short and stout.

Plans Community Relationship. A total of four specimens was collected. They were found only in Lycium.

Seasonal Activity. Members of this species were found during February, April and June. They were most abundant in June.

Comments. This genus was established by LeConte (1866). Casey (1908) named most of the present species. After comparing our specimens with a previously identified *D. knausi*

Casey the present designation was given. This genus is in need of revision.

1(1-4)B-34 *Eusattus dubius* LeConte

Figure IX-B

References. LeConte, Ann. Lyc. N. H. N. Y., V, 1851, pp. 125, 216. Horn. Trans. Amer. Phil. Soc., XIV, New Series, 1870, p. 294; Trans. Amer. Ent. Soc., X, 1882, p. 305, Proc. Cal. Acad. Sci. (2), IV, 1894, p. 423. Casey, Proc. Wash. Acad. Sci., X, 1908, pp. 56, 66. Blaisdell, Proc. Cal. Acad. Sci., XXIV, 1943, p. 192.

Morphological Characteristics. Length 6 to 10 mm; glabrous with a few small hairs laterally. Head sparsely punctate, densely so near the transverse suture; impunctate centrally; front widely dilated; antennae slender; last four segments dilated, the joints loose; apical segment is subcylindrical. Pronotum very minutely punctate; the sides narrowly explanate; angles both apically and basally slightly acute; scutellum wholly obsolete. Elytra as wide as pronotum or only slightly wider; surface faintly wrinkled; punctures fine but distinct; apex obtuse. Prosternum has only a few short hairs; process obtusely rounded. Legs short and stout; anterior tibia tapering into a moderate-sized apical process.

Plant Community Relationships. A total of 43 specimens was collected. The greatest number occurred in the disturbed Grayia-Lycium and Larrea-Franseria and a little over one-tenth in Mixed. These were the only communities in which they were found.

Seasonal Activity. The species was active from December through June and small numbers were collected in October. The greatest numbers were collected in March. Only a few were collected from December through February. After the peak in March, the numbers collected dropped off during April and May and then increased again in June. From Larrea-Franseria specimens were collected during October, January, February, April and June. Activity in disturbed Grayia-Lycium was more intense and for a shorter period. Here there was activity from March through June. From the Mixed community single specimens were taken in March, October and December.

1(1-4)B-35 *Eusattus agnatus* Casey

Reference. Casey, Proc. Wash. Acad. Sci., X, 1908, p. 76.

Morphological Characteristics. Length 9 to 12 mm; broadly rounded; very convex; rather shining, deep black. Head finely wrinkled both above and below the transverse suture; finely granulate posteriorly; last segment of antennae obtriangular. Pronotum slightly explanate, punctures become less distinct dorsally; scutellum completely obsolete. Elytra as wide as the prothorax, parallel, sides straight, surface feebly rugose with sparser muricate punctures, prosternum sparsely punctate, under-surface quite hairy. Legs stout but moderately long, the anterior tibia extended into a long, blunt apical process.

Plant Community Relationships. A total of 206 specimens was collected. They were most abundant in Grayia-Lycium. They were slightly over two-fifths as abundant in Salsola, whereas a few specimens were taken from Mixed and Coleogyne communities. None was found in Artemisia.

Seasonal Activity. This species was active from March through October, with greatest abundance in August. Only a few specimens were taken in March, April, May, June and October. Activity increased abruptly during July and diminished just as abruptly during September. Activity of this species in disturbed Grayia- Lycium began in March and continued through October. In Salsola it did not become active until July and continued through October. It was active only in July and September in Mixed.

1(1-4)C-36 *Coniontis nevadensis carsonica* Casey

Reference. Casey, Proc. Wash. Acad. Sci., X, 1908, p. 85.

Morphological Characteristics. Length 11 to 13 mm; elongate; convex; very dark reddish-brown to black. Head finely but strongly punctate; front very slightly dilated; eyes emarginate. Pronotum almost one-half as wide as long; sides broadly arcuate; finely punctate, with extremely fine, short, light hair in each; slightly alutaceous along suture. Legs moderately short and stocky; tibiae and tarsi with heavy spines; femora punctate.

Plant Community Relationships. A total of 31 specimens was collected. The greatest numbers occurred in the disturbed Grayia-Lycium, with two-thirds of this number in Grayia-Lycium and Mixed communities. These were the only communities in which they were found.

Seasonal Activity. Members of this species occurred from March through September. They were most abundant during July, August and September. They were slightly more abundant

during March and April than they were in May and June. In disturbed Gravia-Lycium they were active from March through August. In Gravia-Lycium their activity was noted only in April, July and August, whereas in Mixed they were active from May through August.

1(1-4)D-37 *Coniontellus argutus* Casey

Figures V-C; XV-H

Reference. Casey, Proc. Wash. Acad. Sci., X, 1908, p. 145.

Morphological Characteristics. The single specimen studied was 7.5 mm in length. Oblong; rather elongate; glabrous, or appearing to be so; reddish brown to black; head very small; equal in length and width; front broadly dilated; eyes divided; antennae short and rather stout. Pronotum broadly arcuate in front; the apex narrower than the base; surface finely punctate. Elytra finely punctate, but very distinct; appearing to be slightly alutaceous. Legs short; very stout with heavy spines.

Plant Community Relationship. A total of 2 specimens was collected. They were collected in the Mixed community in August.

Seasonal Activity. The only collection made of this species was in August.

1(1-5)A-38 *Blapstinus vandykei* Blaisdell

Reference. Blaisdell, Trans. Am. Ent. Soc., LXVIII, 1942, p. 136.

Morphological Characteristics. Length 5 to 6 mm; oblong; moderately convex; black; pubescent. Head widest at the middle; densely and coarsely punctate; stiff black hairs; eyes divided, the upper portion large and round; antennae robust and short; clothed with stiff black hairs. Pronotum twice as wide as long; deeply and coarsely punctate; black hairs arising in each puncture; bisinuate basally. Elytra elongate; sides parallel; broadly rounded posteriorly; broad striae at narrow intervals; stiff, black, decurved pubescence arising from the striae. Legs fairly stout with short spines on tibia; fourth segment of anterior tarsi very short and smaller than third; the fifth segment is long.

Plant Community Relationships. A total of 35 specimens was collected. They were most abundant in Grayia-Lycium. A few specimens were found in Mixed. They were not found in any of the other communities.

Seasonal Activity. This species was active from March to October. There were two peaks of activity—one in March, the other in July. In the other months only a few specimens were collected. In disturbed Grayia-Lycium their activity started in March and continued until June; then in July activity started again and lasted into September. In Grayia-Lycium their activity started in May and lasted into October. In the Mixed community they were active during June and July.

1(1-5)A-39 *Blapstinus pubescens* LeConte

Reference. LeConte, Ann. Lyc. N. H. N. Y., V, 1851, p. 147.

Morphological Characteristics. Length of four specimens studied, 7 to 7.3 mm; elongate; deep reddish brown; short yellowish pubescence. Head deeply and coarsely punctate with slight coalescing; yellowing hairs present around eyes and over vertex; upper portion of eyes large and round; antennae fairly short and gradually thickened toward tip. Pronotum broadly emarginate anteriorly and deeply bisinuate posteriorly; densely and coarsely punctate; yellowish hairs laterally and basally; margins slightly flattened. Elytra elongate; broad costa covered with yellowish scale-like hairs; sulci finely punctate in series. Legs fairly short and stout.

Plant Community Relationship. Only four specimens were collected. They were found near Cane Springs in a Mixed community.

Seasonal Activity. The specimens were collected in June.

Comments. Specimens of this species were compared with specimens of the Horn collection in the Academy of Natural Sciences of Philadelphia and the U. S. National Museum by the senior author.

1(1-5)B-40 *Notibius substriatus* Casey

Figures IX-F; XX-A

References. Casey, Ann. N. Y. Acad., V, 1890, p. 479; Ann. N. Y. Acad., VIII, 1895, p. 622.

Morphological Characteristics. Length 4.5 to 5 mm; oblong; somewhat robust; fairly shiny; black with reddish legs and antennae. Head widest at the middle; bilobed at apex; somewhat coarsely and densely punctate, appearing granular; eyes divided, upper lobe minute; antennae robust, much shorter than head and pronotum. Pronotum one and one-half times wider than long; evenly arcuate at the sides and fringed with

stout hairs, surface coarsely, deeply and strongly punctate, laterally asperate. Elytra as wide as the pronotum, broadly rounded behind, both feebly impressed striae and intervals finely punctate. Legs very stout; anterior tibia dilated, middle and hind tibia with strong short spines.

Plant Community Relationships. A total of 316 specimens was collected. The greatest numbers occurred in the Gravia-Lycium community, with about two-thirds of this number in Salsola. A few specimens were found in Atriplex-Kochia, Mixed, Lycium and Larrea Franseria communities. They were not found in Coleogyne or Pinyon-Juniper.

Seasonal Activity. Members of this species occurred from March through November. They were most abundant in May. There was a slight increase in the numbers collected during April, which resulted in the population boom in May. In June the numbers declined. They steadily decreased in July and August and then increased slightly in September. Only a few specimens were collected in October and November. Activity of this species started in March in disturbed Grayia-Lycium, Grayia-Lycium, and Mixed communities. It continued into November in disturbed Grayia-Lycium, died out in October in Grayia-Lycium, whereas in Mixed they had further activity only in May, June, July and September. In Salsola they were active in July and August, whereas in Larrea-Franseria and Atriplex-Kochia they were active only in July.

1(1-5)C-41 *Conibiosoma elongatum* (Horn)

Figures V-D; XVI-A

References. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, p. 351. Casey, Ann. N .Y. Acad., V, 1890, p. 476.

Morphological Characteristics. Length constant around 4 mm; elongate parallel; convex; shining; head and pronotum reddish-brown, elytra black. Head wider than long; finely, rather sparsely punctate; eyes divided; superior portion small and linear; antennae very robust; compact; shorter than head and pronotum; last three segments moderately dilated. Pronotum wider than head; finely, sparsely punctate towards the middle, denser and more coarse laterally. Elytra equal in width to the pronotum; sides nearly straight; even rows of fine punctures; the striae very feebly impressed, the intervals evenly punctate with each bearing a stiff seta. Legs moderate, tibiae not dilated.

Plant Community Relationships. A total of 60 specimens was collected. The greatest numbers occurred in Lycium, with one-half this number in Larrea-Franseria and about one-third in Grayia-Lycium. In Coleogyne this species was one-fifth as abundant as in Lycium. They were one-fifth as abundant in Atriplex-Kochia and one-sixth as abundant in Mixed, whereas there were only a few specimens collected in Salsola. They were not found in Pinyon-Juniper or Artemisia.

Seasonal Activity. Beetles of this species were active from April through October. They were most abundant in May and July. In June, August and September slightly more than one-half as many specimens were collected as in May and July. Only a few specimens were taken in October. They became active in April in Lycium, disturbed Grayia-Lycium, Coleogyne and Mixed communities. They remained active until September in Lycium; August in disturbed Grayia-Lycium; July and August in Coleogyne; and May, July and September in Mixed. They were active in Larrea-Franseria during May, July and September, whereas in Grayia-Lycium they were active from May through July and in Atriplex-Kochia community in June and July. The collection in Salsola was made in October.

1(1-6)A-42 *Anemia californica* Horn

Figure XV-C

Reference. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, p. 378.

Morphological Characteristics. Length 3.5 to 4 mm; short; oval; robust; deep reddish-brown; winged. Head broad; densely and rather coarsely punctate; apex deeply emarginate; sides broadly dilated; eyes deeply emarginate; superior portion small; antennae short; robust; thicker at tip; last segment longer than tenth and rounded at tip. Pronotum nearly three times as broad as long; convex; densely and coarsely punctate; fringed with long yellowish hairs. Elytra broadly oval, scarcely longer than wide; sides fringed with long yellowish hairs; surface deeply and coarsely punctate. Legs short; robust; tibiae all dilated, covered with long yellowish hairs.

Plant Community Relationship. A total of 5 specimens was collected. They were found in the Lycium community.

Seasonal Activity. This species was collected in May and June.

Comments. Beetles of this species are nocturnal fliers. They were collected by their attraction to ultra-violet light. Not enough collections were made with the ultra-violet light to

determine this species' seasonal range of activity or community restrictions. Their body form resembles the Scarabaeidae.

1(1-7)A-43 *Coelocnemis punctata* LeConte

References. LeConte, Proc. Acad. Nat. Sci., VII, 1854, p. 225. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, p. 337. Casey, Memoirs on the Coleoptera, XI, 1924, p. 319.

Morphological Characteristics. Length of specimen 20 mm; elongate; convex: dull black; moderately shining; resembles *Eleodes.* Head longer than wide; deeply, finely, and rather thickly pubescent; eyes large and reniform; antennae short and stout; first segment long and broad; the second segment very short; last five segments slightly compressed. Pronotum wider at apex than base; almost as broad as long; surface finely punctate. Elytra finely punctate and finely wrinkled; posterior rather suddenly sloping. Legs fairly long; tibiae and tarsi with fine silken pubescence underneath.

Plant Community Relationship. The single specimen collected was in Pinyon-Juniper. It was collected by hand from under rocks.

Seasonal Activity. This specimen was collected on July 26.

Comments. This genus needs to be completely revised.

1(1-7)B-44 *Alaephus nevadensis* Tanner, New Species

Figures IV-A; XV-A; XXI

Form elongate, rufotestaceous, median and lateral portions of the prothorax and elytra slightly paler; head and prothorax densely subrugosely punctate, dull in contrast to the rest of the body; elytra with prominent closely set punctures with inconspicuous short pale setae.

Head small, widest at the eyes, which is one-half as wide as the prothorax; maxillary palpi prominent, third segment hatchet-shaped. Eyes small, not noticeably projecting beyond the sides of the front; width between the eyes above, five times the length of the second joint of the antennae, beneath separated by four and three-tenths the length of the second antennal segment; antennae slender, less than half the length of the body; third joint only a little longer than the fourth segment; tenth segment slightly longer than the eleventh.

Prothorax two-thirds wider than long; apex four-fifths as wide as base, sides evenly rounded, not sinuate before the hind angles, which are obtuse; disk evenly convex.

Elytra four times as long and twice as wide as the prothorax; humeral angle obtuse, sides parallel and arcuate beyond the middle; punctures under high magnification muricate with pale short hairs, noticeable near the declivity and margin. Scutellum prominent, wedge-shaped. Prothorax beneath rugulose punctate. Metasternum and abdomen finely, sparsely punctate; each puncture bearing a pale decumbent seta. Basal joint of the hind tarsus only a fraction longer than the distal fourth joint.

Length 6.6 mm; width 3 mm.

Type locality: Mercury, Nye County, Nevada. Collected by members of Brigham Young University, AEC Project, 1961-62. Type and four paratypes in entomological collection at Brigham Young University.

Remarks: *Nevadensis* belongs in Fall's couplet—eyes small, etc.—and is related to Horn's *pallidus.* It is a smaller species, darker, without the shining elytrae. Eyes are separated both

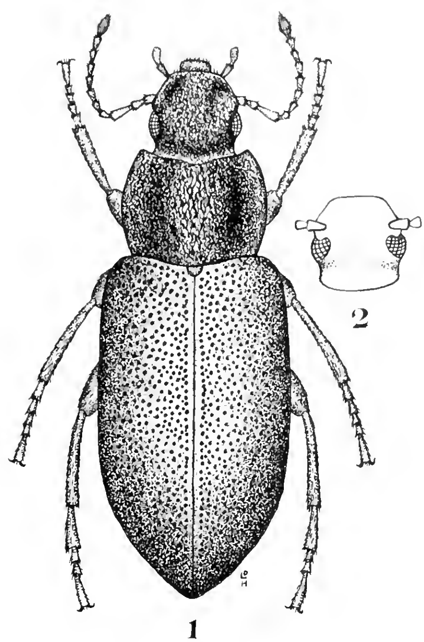

Figure XXI. *Alaephus nevadensis* Tanner. (1) Dorsal view of female; (2) dorsal view of head showing shape and distance of separation of the eyes.

above and beneath more than those in *pallidus*, antennae are shorter, the fourth joint is almost as long as the third one. Basal joint of hind tarsae shorter than in *pallidus*.

Plant Community Relationship. Four specimens of this species were collected on July 25, 1961, on *Elymus cinereus*, a large-type bunch grass, in a Mixed community and one on July 1, 1961, in a Mixed community.

Comments. The specimen collected on July 1 was in a Mixed community near Cane Springs in the same can trap as *Blapstinus pubescens*.

1(1-7)C-45 *Eupsophulus castaneus* Horn
Figures IX-A, XIX-I

Reference. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, p. 347.

Morphological Characteristics. Length 9 to 14 mm; elongate; chestnut brown; moderately shining. Head elongate; front narrowing anteriorly and broadly emarginate; very sparsely punctate; eyes broad; antennae longer than the head and pronotum; last segment long and slender. Pronotum subquadrate; slightly broader than long; surface sparsely punctured. Elytra elongate-oval; broader at base than pronotum; humeri distinct; sparsely punctured. Legs slender; tarsi long with short spinuous hairs.

Plant Community Relationships. A total of 35 specimens was collected. The greatest numbers occurred in a Mixed community, with under one-half this number in Lycium and one-third in Gravia-Lycium. In Larrea-Franseria they were one-sixth as abundant as in Lycium. They were not present in Atriplex-Kochia, Salsola, Coleogyne and Pinyon-Juniper communities. This species is a nocturnal flying form. Most of the collections in Lycium and Mixed were made by the beetle's being attracted to ultra-violet light.

Seasonal Activity. This species was active during May, June and July.

Comments. Due to the few specimen collection attempts made with ultra-violet light it is not possible to make an accurate determination of seasonal activity or relative abundance in the separate communities.

1(1-8)A-16 *Helops attenuatus* LeConte
Figures IX-D, XIX-K

References. LeConte, Ann. Lyc. N. Y., V, 1851, p. 137. LeConte and Horn, Class. Col. N. Amer., 1883, p. 240. Horn, Trans. Amer. Phil. Soc., XIV, New Series, 1870, p. 397; Trans. Amer. Ent. Soc., VIII, 1880, p. 152. Seidlitz, Naturg. Ins. Deutschl., V, 1896, p. 696.

Morphological Characteristics. Length 5 to 10 mm, elongate; convex; varies from reddish-brown to black with some having a lighter head and pronotum than elytra. Head fairly long; front dilated; coarse, dense punctures; eyes transverse and large; antennae long with outer joints slightly compressed and pubescent. Pronotum longer than broad; finely, densely punctate. Elytra elongate-oval; almost subcylindrical; humeri rounded; striae of coarse punctures. Legs long and fairly stout; heavy pubescent pad on all but the last segment of the tarsi.

Plant Community Relationships. A total of 140 specimens was collected. They were most abundant in Gravia-Lycium and about four-sevenths as abundant in the Larrea-Franseria, Coleogyne, Salsola and Atriplex-Kochia. In Mixed they were two-sevenths as abundant as in disturbed Gravia-Lycium. They were not present in Lycium, Pinyon-Juniper, or Artemisia.

Seasonal Activity. This species was active during every month except September, with the greatest numbers being collected during February. Only a few specimens were collected in May, June, July, August and October. There was an abrupt increase in the numbers collected during November, and then they remained at about the same level through December, January, March and April. In disturbed Gravia-Lycium and Mixed, activity began in October. They remained active in disturbed Gravia-Lycium until June, whereas in Mixed they were active only until March. In Gravia-Lycium, Salsola and Larrea-Franseria they were active through March, and in Salsola into February. In Coleogyne they were active in February, March and April; whereas in Atriplex-Kochia they were active in February, April, May, August and October.

DISCUSSION

In the desert areas of southwestern United States the darkling beetles constitute a conspicuous part of the ground-dwelling insects. They are primarily nocturnal and spend the day under rocks, debris, loose bark or in rodent burrows. Occasionally on cloudy days they may be seen lumbering along the desert floor. To the casual observer of such desert regions, it may seem surprising that 46 species of tenebrionids occur in the relatively small area comprising the Nevada Test Site. However, upon closer examination of the vegetation, it is apparent that a variety of habitats exists for which many species of beetles may be indigenous. Inasmuch as this is apparently one of the first studies of its kind dealing with tenebrionids of a specific area, investigations in other desert areas may demonstrate these beetles to be even more common than this study has indicated.

Abundance of Species

At the Nevada Test Site the number of species of beetles found varied between plant communities. The Mixed and disturbed Grayia-Lycium communities supported the largest number of species, whereas the fewest were found in Atriplex-Kochia and Pinyon-Juniper. These relationships may be explained on the basis of the greater variety of plant species which occur there. Such a mixture likely makes available a large variety of food for the plant-feeding darkling beetles. There are also a variety of microhabitats available to the many species. Comparing this environment with that of the Atriplex-Kochia where relatively few species were present, it is evident that in the latter community there are few plant species other than the two predominant ones. The vegetation is very short and sparse, and the number of micro-habitats is greatly reduced. These factors likely influence the number of species that may inhabit this community. The Larrea-Franseria and Lycium communities, which are typical of the Mohave Desert, supported almost as many numbers of species as the Grayia-Lycium, which is more typical of the Great Basin Desert. Other communities such as Atriplex-Kochia and Coleogyne supported fewer species than Larrea-Franseria and Lycium, even though they occupied the same geographic localities. Pinyon-Juniper, typically Great Basin, supported the least number of species of all communities. Very likely the higher altitude, lower temperatures, increased moisture and longer periods of snow cover were limiting factors compared to many species found in the other communities. This would lead one to assume that similar communities of the Mohave Desert may support a greater number of species than the Great Basin communities.

In areas where nuclear detonations have disturbed the normal biotic conditions, a different species association occurs. The disturbed Grayia-Lycium had a greater number of species than Grayia-Lycium whereas Salsola had less. In these areas the Salsola is just beginning the process of revegetation, and the number of invader plants are few. Disturbed Grayia-Lycium, however, is an ectonal area between the more stable, undisturbed plants and those areas where the native plants were completely eliminated. This community, then, may share species that are indigenous to the other two.

Populations

With reference to total populations of all tenebrionids, the disturbed Grayia-Lycium contained approximately one-third more individuals than Larrea-Franseria. Lycium and Coleogyne supported only one-fourth as many specimens as did disturbed Grayia-Lycium. The Mixed community, in which the largest number of species was found, supported only one-seventh the population of disturbed Grayia-Lycium. The number of specimens in Atriplex-Kochia was considerably less than in any other community.

With reference to all tenebrionids there were two seasonal population peaks. In May and September over 2,000 specimens were collected. Approximately 1,500 were taken in June, 1,000 in July, and 1,500 in August. From the peak in September there was a sharp decline in numbers collected until December, when fewer than 100 individuals were found.

In Coleogyne, Grayia-Lycium and Mixed communities the largest number of beetles collected was in September, with a lower peak in April and May (Figs. X and XII). The number collected in Larrea-Franseria, Lycium and Atriplex-Kochia increased gradually from a December low to a high in August and September (Fig. XI). Following this the number collected declined rapidly. High populations occurred in disturbed Grayia-Lycium and Salsola during March, April and May, when the numbers of specimens taken were over a thousand each month. Collections declined in the following months, with a small increase in August and September (Figs. X and XII).

Plant Community Relationships

Certain species demonstrated apparent plant community association more than others. These associations were shown by Allred, *et al.* (1963a, pp. 42-43).

One species, *Eleodes obscura sulcipennis*, was present in every community at the test site, whereas others were variously distributed in their occurrence.

Six species, *E. extricata frigida*, *E. tenebrosa*, *E. brunnipes brevisetosa*, *E. nigrina*, *Embaphion elongatum*, and *Coelocnemis punctatus*, were present only in the Pinyon-Juniper. These apparently are restricted to areas of higher elevation, cooler climate, and more abundant precipitation. *Blapstinus vandykei* and *Alaephus nevadensis* were found only in Mixed vegetation near Cane Springs, where an abundance of lush vegetation near the spring may account for their presence. *Coniontellus argutus* was found only in Mixed, an area where *Artemisia tridentata* was rather abundant. *Sphaeriontis dilatata* was collected only in Lycium, which is 976 meters above sea level, one of the lowest areas in elevation at the test site. *Anemia californica* also was taken only in Lycium by the use of ultraviolet light. It may be shown to be more widely distributed should this collecting technique be used to a greater extent in other areas.

It is interesting to note that with reference to those species that were found in only one or a few communities, the total number of individuals was relatively low. Numbers of individuals of species which were more widely distributed were considerably higher.

Seasonal Activity

During July and August there were more species active over the test site than at any other time of the year. Thirty-three species were found during July and 31 in August. Beginning in September there was a steady decline in the number of species active until February, when only nine were found. In March species activity increased, and 20 were found. In April the number increased to 27, dropped to 22 in May, then increased to 27 again in June.

The length of time that the different species of tenebrionids were active varied considerably. Many were active for a specific season; others persisted for two or three seasons, whereas some were active all year. Although some were more active in winter, the majority were inactive during the colder months.

Three species, *Edrotes orbus*, *Araeoschizus sulcicollis* and *Eleodes armata*, were active every month of the year. *E. orbus* was most active during the winter and spring, whereas the other two demonstrated greatest activity in summer and autumn.

Three species, *Euschides luctatus*, *Trichiasida acerba* and *Helops attenuatus*, were active from the beginning of autumn through the spring. One species, *Eusattus dubius*, was active during the winter and spring.

In the spring considerable activity was manifest by many species. Some remained active only through summer (*Centrioptera muricata*, *Cryptoglossa verrucosa*, *Anepsius brunneus*, *Eleodes longipilosa*, *Sphaeriontis dilatata*, *Coniontis nevadensis*, *Blapstinus carsonica pubescens* and *Eupsophulus castaneus*), whereas others continued into autumn (*Metoponium convexicolle*, *Triorophus laevis politus*, *Eleodes carbonaria immunis*, *E. obscura*, *E. grandicollis valida*, *E. hispilabris sculptilis*, *Trogloderus costatus nevadus*, *Eusattus agnatus*, *Notibius substriatus* and *Conibiosoma elongatum*).

Those active only during the summer were *Chilometopon abnorme*, *Metopoloba bifossiceps*, *Eleodes extricata frigida*, *E. tenebrosa*, *E. nigrina*, *E. brunnipes brevisetosa*, *Embaphion elongatum*, *Coniontellus argutus*, *Blapstinus pubescens*, *Anemia california*, *Coelocnemis punctata* and *Alaephus nevadensis*. Others that demonstrated increased activity in the summer and continued into autumn were *Hylocrinus laborans*, *Pelecyphorus pantex*, *P. semilaevis*, and *Eleodes dissimilis nevadensis*. One species, *E. longicollis valida*, was active only during the autumn.

Life History and Food Habits

Tanner (1961) reported that some members of the genus Eleodes hibernated ". . . in the adult or partly grown larval stage." O'Kane (1924) states that some tenebrionids have one generation annually. As shown by this study there are two population peaks—May and September. These two peaks suggest that some species metamorphose from pupa to adult in the autumn and over-winter as adults. Others over-winter as larvae and emerge as adults in the spring. This may account for the two seasonal peaks in May and September and low numbers during July and the winter months.

SUMMARY

The intent of this study conducted over a period of three years was to (1) provide descriptions of the species of tenebrionids found at the Nevada Test Site, (2) determine their relative abundance, (3) determine their seasonal activity, and (4) ascertain their plant community relationships.

A total of 14,650 beetles representing 46 kinds of tenebrionids was collected with sunken can traps, by hand, and ultra-violet light. Collections were made at regular intervals in the following plant communities: Larrea-Franseria, Lycium, Atriplex-Kochia, Grayia-Lycium (disturbed and undisturbed areas), Salsola, Coleogyne, Pinyon-Juniper, and Mixed.

The data obtained from this study indicate that (1) more species were present in some plant communities than in others; (2) in nuclear disturbed areas a larger number of species was present than in undisturbed areas; (3) some species were more closely associated with some plant associations than with others; (4) those species that were not widely distributed ecologically were fewer in number of individuals, whereas those that were widespread occurred in larger numbers, relatively speaking; (5) the species demonstrated variation in seasonal activity in that some were active for short periods whereas others were active during the whole year; and (6) the two seasonal peaks in population are indicative that some species over-winter as adults whereas others over-winter as larvae.

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BRIGHAM YOUNG UNIVERSITY
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OBSERVATIONS ON THE BIOLOGY, ANATOMY, AND MORPHOLOGY OF *OTOBIUS LAGOPHILUS* COOLEY AND KOHLS

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OBSERVATIONS ON THE BIOLOGY, ANATOMY, AND MORPHOLOGY OF *OTOBIUS LAGOPHILUS*[1]

by

C. Selby Herrin[2]

and

D Elden Beck[2]

INTRODUCTION AND REVIEW OF THE LITERATURE

The principal objective of this study is to bring up to date information on geographic distribution, seasonal occurrence, and host-parasite relationship of the soft-bodied tick *Otobius lagophilus* Cooley and Kohls in western North America. Notes on life history and disease transmission potential are also added. Drawings and descriptions of some external anatomical and morphological features in the adult, nymphal, and larval stages are given to assist in the identification of individual organisms. A pictorial key is included to facilitate the identification and separation of the two species, *O. lagophilus* and *O. megnini* Dugés.

The spinose ear tick was described by Dugés (1884) as *Argas megnini*. It was later removed from *Argas* and placed in the genus *Ornithodoros* by Neumann (1896). Banks (1912) separated it from *Ornithodoros* and proposed the new genus *Otobius*, with *O. megnini* as the type. In 1940 Cooley and Kohls described the second species of the genus, *O. lagophilus*. Previous to 1940 there were several reports of collections of rabbit ticks identified as *Ornithodoros megnini* (Hadwen, 1913; Cooley, 1932). These were later shown to be *O. lagophilus*. The first detailed study of the genus was made by Cooley and Kohls in 1944.

In their paper describing the adults and nymphs of *O. lagophilus*, Cooley and Kohls (1940) included three photographs of whole ticks and several drawings of mouthparts, spines, and legs. The morphological and anatomical differences between *O. megnini* and *O. lagophilus* were noted, and all available collection records were reported. Later Cooley and Kohls (1944) published this same material with a key for the separation of nymphs and adults of the two species, and brought collection records up to date.

The earliest recorded collections of *O. lagophilus* were from Lethbridge, Alberta, Canada, in 1912 (Hadwen, 1913) and Powderville, Montana, in 1916 (Cooley, 1932). Additional collections were later made in the same area of Canada (Cooley and Kohls, 1944). The species is now known from Montana (Cooley and Kohls, 1944), Wyoming (Cooley and Kohls, 1940, 1944), Colorado (Cooley and Kohls, 1944), Utah (Beck, 1955; Hopla, 1955; Rosasco, 1957; Bacha, 1957), Nevada (Cooley and Kohls, 1940, 1944; Philip, Bell, and Larson, 1955; Beck, Allred, and Brinton, 1963), California (Cooley and Kohls, 1940; Loomis, 1953; Ryckman, Lindt, Spencer, and Lee, 1955), and Mexico (Silva-Goytia and Elizondo, 1952b). Additional records from Nevada and Utah are included in this paper.

Important studies on life history have been made by Hopla (1955) and Bacha (1957). Some notes have been published by Woodbury (1955), Loomis (1961), and Rees (1962).

The first evidence of *O. lagophilus* as a potential vector of disease was given by Silva-Goytia and Elizondo (1952b) in their work on Rocky Mountain spotted fever in Mexico. A short time later Philip, et. al. (1955) reported finding rickettsiae related to Rocky Mountain spotted fever and Colorado tick fever virus in *O. lagophilus* in Nevada. Eklund, Kohls, and Brennan (1955) isolated the Colorado tick fever virus once from *O. lagophilus* collected in northern Nevada and in northern Utah. The only other implication of this species as a potential disease vector was by the workers in the Uni-

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versity of Utah Ecological and Epizoological Research Unit at Dugway, Utah, in which they demonstrated by laboratory experiments the capability of this tick as a reservoir and agent of transfer of tularemia (Vest, 1957, 1959, 1960, Rees, 1962).

Since the original description by Cooley and Kohls (1940) little work has been done on the anatomy and morphology of this tick. Cooley and Kohls (1944) listed some features in their key for the separation of nymphs and adults of *O. lagophilus* and *O. megnini*. Bacha (1957) made some notes on this subject in connection with life history studies.

MATERIALS AND METHODS

Rabbit hosts were collected afield by shooting them. Each dead rabbit was placed in a paper bag and returned to the laboratory where it was carefully examined in a large, white enamel pan under incandescent illumination. The warmth provided by the lamp stimulated tick movement. Most larval and nymphal ticks were removed by combing the hair about the face near the vibrissae and eyes, and on the ears and neck. The adults are nonparasitic and field collections were specimens which were found on the ground.

Specimens of all stages of development were preserved in 70% ethyl alcohol contained in two-dram shell vials. An identification tag with field number, place, host, and name of collector was placed in each vial. The field number was recorded in a field notebook, where additional data about each collection were described in some detail. When the specimen was identified to species and the stage of development determined, data from all sources about the collection were then placed on data cards designed for that purpose.

Some engorged larvae and nymphs were kept alive and reared to successive stages in order to get unengorged specimens for anatomical studies. Rearing was accomplished by placing the specimens in large, cotton-stoppered vials. Some were maintained at room temperature and humidity and others in containers where humidity and temperature were controlled. Because no appreciable differences between the two methods were observed, for our purposes it was finally decided to use room conditions for rearing.

Most specimens used for anatomical and morphological studies were provided by Dorald M. Allred, Brigham Young University. Two nymphal *O. megnini* cleared and mounted on microslides sent to us in a lot of ticks from Clyde M. Senger of Western Washington State College, Bellingham, Washington, were used in making structural drawings for the pictorial key. Larvae of *O. megnini* were obtained from the Rocky Mountain Laboratory, Hamilton, Montana.

Nymphs and adults were prepared for study by using a teasing needle to remove the brittle, thin, translucent covering over the body. Larval specimens and nymphal skins were mounted on microslides. Specimens were first placed in Nesbitt's solution until they became clear and transparent. Ticks were then mounted on microslides in Hoyer's medium.[3] Specimens were oriented in the medium to the desired position, and then a coverslip was applied. Mounted specimens were warmed at brief intervals over an alcohol lamp until the legs were uniformly extended, then placed in a warming oven at a temperature of about 50°C. for two to three days to enhance solidification of the mounting medium.

Adult and nymphal specimens were placed in a watch glass or similar container, covered with 70% ethyl alcohol, and examined with a Leitz stereomicroscope under magnifications of 32 and 72 diameters. Illumination was provided by two A. O. Universal Illuminators placed about 4 inches from the specimen. Mounted larval specimens and nymphal skins were examined with a Zeiss phase-contrast microscope under magnifications of 128 and 320 diameters.

Both the Leitz stereomicroscope and the Zeiss phase-contrast microscope were equipped with a grid in each left eyepiece to facilitate accurate drawings. As each specimen was examined a penciled outline sketch was made on Quadrille paper ruled 4 squares to the inch. This sketch was then transferred, with the use of tracing paper, to medium weight, cold pressed surface illustration board. Details of anatomical and morphological structure were added to the sketch; then the drawings inked. When all drawings were completed they were photographically reduced to the desired size for publication, and labels added.

[3]See Evans, Sheals, and Macfarlane (1961), and Strandtmann and Wharton (1958).

GEOGRAPHIC DISTRIBUTION

All available collection records and previously published data are contained in Table I. Figure 2 shows the general location of reported collections as well as a proposed region of distribution based on these data.

O. lagophilus occurs in the arid and semiarid regions of western North America. It has been reported primarily from the desert regions of the westen United States with but two exceptions - one from Lethbridge, Alberta, Canada (Cooley and Kohls, 1944), and the other from Matamoros, Coahuila, Mexico (Silva-Goytia and Elizondo, 1952b). The Mexico collection is far removed from the most southerly common distributional range in the United States, whereas the Canada collection is within the normal range.

To a marked extent the known distribution of *O. lagophilus* follows a pattern similar to that of the black-tailed jack rabbit, *Lepus californicus deserticola*. The range of this rabbit is southern Idaho, most of Nevada, all of Utah except the eastern part, western Arizona, and the southeastern part of California. Almost all specimens of *O. lagophilus* collected from *L. californicus* have been in this region. Outside the range of *L. californicus deserticola* most collections have been from *L. townsendii* and *Sylvilagus* species.

L. californicus deserticola is typically found in the Upper Sonoran and Transition Life-zones, although a few occur at higher elevations. Known collections of *O. lagophilus* from this host have been no higher than the Upper Sonoran Life-zone.

Further extensive and intensive collections throughout western North America, particularly within the range of *L. californicus* and *L. townsendii*, may extend the geographic and host distribution of this tick.

SEASONAL OCCURRENCE

Lack of continuous collections over a twelve-month period in given localities prevents an accurate determination of seasonal occurrence to be made. Seasonal occurrence likely varies between Montana and southern Nevada. Nevertheless, sufficient data are available to give some basis for the graphic representation in Figure I. In one development stage or another, *O. lagophilus* has been collected in every month of the year. Most collections of *O. lagophilus* have been in the nymphal stage. Nymphs have been collected from rabbits in every month of the year, with the peak season in May, June, July, and August. Larvae have been taken from rabbits in February, May, August, and November. Adults have been collected from the ground in May, June, August, and September. Additional collection data will make a more accurate determination of seasonal occurrence possible.

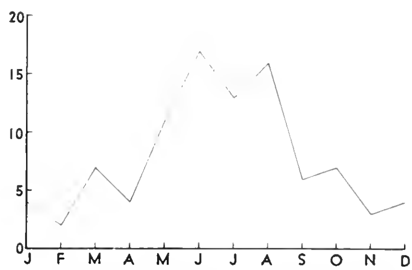

Fig. 1. Seasonal occurrence of *O. lagophilus*, expressed as number of collections per month.

HOST-PARASITE RELATIONSHIP

With few exceptions *O. lagophilus* parasitizes lagomorphs. One collection from the cat (*Felis catus*) at Lethbridge, Alberta, Canada (Cooley and Kohls, 1944) is known, and several from the burro (*Equus asinus*) at Matamoros, Coahuila, Mexico (Silva-Goytia and Elizondo, 1952b). Strangely, the latter authors failed to find *O. lagophilus* on rabbits. The black-tailed jack rabbit, *L. californicus*, is the preferred host in the western United States, although in

Table 1. Collection Data of *Otobius lagophilus* Cooley and Kohls

State or Country	Locality	Date	Host Animal or Source	No. Collected L	N	A	Collector or Author
California	Barstow, San Bernardino Co.	20 June 1924	*Lepus californicus*		17		U. of Mich. Mus. Zool. (R.M.L.[1] #16895)
California	Lonetree Cyn., Tracy, San Joaquin Co.	Aug 1951	entrance to active rodent burrow	200		5	E. C. Loomis
California	Lonetree Cyn., Tracy, San Joaquin Co.	June 1952	entrance to active rodent burrow		2	24	E. C. Loomis
California	Reche Cyn., Riverside Co.	10 Oct 1951	*Sylvilagus audubonii*		1		R. E. Ryckman, et. al.
Canada	Lethbridge, Alberta	2 Oct 1912	*L.* species		3		A. Watson (R.M.L. #16124)
Canada	Lethbridge, Alberta	Oct 1912	*L.* species		1		A. Gibson (R.M.L. #16125)
Canada	Lethbridge, Alberta	22 Dec 1931	*L.* species		1		E. H. Strickland (R.M.L. #16290)
Canada	Lethbridge, Alberta	11 Dec 1941	*Felis catus* (cat)		1		H. L. Seamans (R.M.L. #19349)
Colorado	Jackson Co.	13 Sept 1940	*L.* species		26		Colo. Game & Fish Dept. (R.M.L. #17131)
Idaho	Mayfield, Ada Co.	30 June 1932	*L.* species		16		R.M.L. (#8104A)
Idaho	Grandview, Owyhee Co.	3 July 1932	*L.* species		5		R.M.L. (#8124A)
Idaho	Mayfield, Ada Co.	11 July 1932	*L.* species		1		R.M.L. (#8183A)
Idaho	Mayfield, Ada Co.	12 Aug 1932	*L.* species		2		R.M.L. (#8401A)
Idaho	Grandview, Owyhee Co.	15 Aug 1932	*L. californicus*		4		R.M.L. (#8431A)
Idaho	Mayfield, Ada Co.	21 Aug 1932	*L. californicus*		1		R.M.L. (#8483A)
Idaho	Grandview, Owyhee Co.	10 Sept 1932	*L.* species		9		R.M.L. (#8613A)
Idaho	Mayfield, Ada Co.	25 Apr 1933	*L.* species		1		R.M.L. (#9042B)
Idaho	Mayfield, Ada Co.	18 Aug 1933	*S.* species		1		R.M.L. (#8474A)
Idaho	Canyon Co.	16 June 1936	*L.* species		2		Plague Lab. P.H.S.[2] (R.M.L. #12377A
Idaho	Rupert, Minidoka Co.	16 June 1936	*S.* species		1		R.M.L. (#16750)
Mexico	Matamoros, Coahuila	Oct 1951 to June 1952	*Equus asinus* (burro)		2 lots		R. Silva-Goytia and A. Elizondo
Montana	Powderville	1916	"rabbits"		X		R.R. Parker
Montana	Bozeman, Gallatin Co.	3 June 1930	*L. townsendii*		2		R.M.L. (# ?)
Montana	Roy, Fergus Co.	25 Sept 1931	*L.* species		4		R.M.L. (#7978)
Montana	Deer Lodge, Powell Co.	2 Oct 1934	"rabbit"		10		R.M.L. (#10159)
Montana	Miles City, Custer Co.	6 June 1935	*L.* species		3		R.M.L. (#11108)
Montana	near Dillon, Beaverhead Co.	13 July 1935	*L.* species		30		R.M.L. (#11154)
Montana	near Dillon, Beaverhead Co.	16 July 1935	*L.* species		2		R.M.L. (#11183)
Montana	near Dillon, Beaverhead Co.	6 Aug 1935	*L. townsendii*		22		R.M.L. (#11235)
Montana	near Dillon, Beaverhead Co.	2 July 1937	*L. townsendii*		4		R.M.L. (#13263)
Montana	Cameron, Madison Co.	5 Jan 1940	*L. townsendii*		1		R.M.L. (#16218)
Nevada	41 mi. NE Ely, White Pine Co.	17 Apr 1932	*L.* species		1		R.M.L. (#8062)
Nevada	12 mi. SW Fallon, Churchill Co.	10 May 1940	on ground			1	R.M.L. (#17850)
Nevada	near Lovelock, Pershing Co.	11 Sept 1941	animal burrow			1	R.M.L. (#19270)
Nevada	near Battle Mtn. and Winnemucca, Humbolt Co.	summers of 1951-52	*L. californicus*		X		Philip, et. al.
Nevada	Nevada Test Site, Nye Co.	18 Aug 1960	*L. californicus*		5		B.Y.U.[3] (#5247)
Nevada	Nevada Test Site, Nye Co.	9 Jan 1961	*L. californicus*		4		B.Y.U. (#5221)
Nevada	Nevada Test Site, Nye Co.	18 May 1961	*L. californicus*	15	3		B.Y.U. (#6279)
Nevada	Nevada Test Site, Nye Co.	18 May 1961	*L. californicus*		3		B.Y.U. (#5108)
Nevada	Nevada Test Site, Nye Co.	18 May 1961	*L. californicus*		3		B.Y.U. (#6278)
Nevada	Nevada Test Site, Nye Co.	18 May 1961	*L. californicus*	4	22		B.Y.U. (#5109)

Table 1. (continued)

State or Country	Locality	Date	Host Animal or Source	No. Collected L	N	A	Collector or Author
Nevada	Nevada Test Site, Nye Co.	18 May 1961	*L. californicus*	15			B.Y.U. (#6305)
Nevada	Nevada Test Site, Nye Co.	4 June 1961	*L. californicus*		2		B.Y.U. (#5161)
Nevada	Pahroc Summit, Nye Co.	9 June 1961	*L. californicus*		60		B.Y.U. (#4996)
Nevada	Nevada Test Site, Nye Co.	11 June 1961	*L. californicus*		51		B.Y.U. (#4994)
Nevada	Nevada Test Site, Nye Co.	11 June 1961	*L. californicus*		1		B.Y.U. (#5119)
Nevada	Mercury, Nye Co.	20 July 1961	*L. californicus*		2		B.Y.U. (#6280)
Nevada	Mercury, Nye Co.	20 July 1961	*L. californicus*		3		B.Y.U. (#4965)
Nevada	Nevada Test Site, Nye Co.	5 Aug 1961	*L. californicus*		1		B.Y.U. (#5163)
Nevada	Wells, Elko Co.	11 Aug 1961	*L. californicus*		1		B.Y.U. (#5048)
Nevada	Nevada Test Site, Nye Co.	11 Aug 1961	*L. californicus*		2		B.Y.U. (#5167)
Nevada	Nevada Test Site, Nye Co.	15 Aug 1961	*L. californicus*		1		B.Y.U. (#5153)
Nevada	Nevada Test Site, Nye Co.	15 Aug 1961	*L. californicus*	2	37		B.Y.U. (#5064)
Nevada	Nevada Test Site, Nye Co.	17 Sept 1961	*L. californicus*		1		B.Y.U. (#5078)
Oregon	near Bend, Deschutes Co.	3 Oct 1940	in decaying log frequented by rabbits		3		R.M.L. (#17390)
Utah	Fairfield, Utah Co.	4 Sept 1948	*L. californicus*		6		C. E. Hopla
Utah	Lucin, Box Elder Co.	19 June 1952	*L. californicus*		1		B.Y.U. (# ?)
Utah	Locomotive Springs, Box Elder Co.	20 June 1952	*S. nuttallii*		1		B.Y.U. (#2188)
Utah	Fish Springs, Juab Co.	30 Oct 1953	*L. californicus*		18		B.Y.U. (#3786)
Utah	Fish Springs, Juab Co.	6 Feb 1954	*L. californicus*	175	6		B.Y.U. (#3804)
Utah	3½ mi. SE Roosevelt, Duchesne Co.	3 Apr 1954	*L. townsendii*		3		B.Y.U. (#3890)
Utah	3 mi. SE Wig Mtn., Tooele Co.	2 Nov 1954	*L. californicus*	8			M. E. Rosasco
Utah	3 mi. SE Wig Mtn., Tooele Co.	4, 11, 25 May & 24 Nov 1954 11 Jan and 15 Mar 1955	*L. californicus*		52		M. E. Rosasco
Utah	Dugway Valley, Tooele Co.	15 Mar 1955	*L. californicus*		X		Wm. J. Bacha Jr.
Utah	Rush Valley, Tooele Co.	14 July 1955	*L. californicus*		73		Wm. J. Bacha Jr.
Utah	Rush Valley, Tooele Co.	14 July 1955	*L. californicus*		102		Wm. J. Bacha Jr.
Utah	Dugway Valley, Tooele Co.	21 Mar 1956	*L. californicus*		1228		Wm. J. Bacha Jr.
Utah	mouth of San Rafael River, Emery Co.	4 June 1957	under rock			1	B.Y.U. (#6523)
Utah	4 mi. W. Rosette, Box Elder Co.	17 Mar 1961	*S. idahoensis*		4		B.Y.U. (#4901)
Utah	11 mi. SW Rosette, Box Elder Co.	18 Mar 1961	*S. idahoensis*		10		B.Y.U. (#4905)
Utah	11 mi. SW Rosette, Box Elder Co.	18 Mar 1961	*S. nuttallii*		2		B.Y.U. (#4906)
Utah	Rosette, Box Elder Co.	7 Aug 1961	*S.* species		1		B.Y.U. (#5027)
Wyoming	Lander, Fremont Co.	2 Aug 1935	"rabbit"		X		R.M.L. (#11278)
Wyoming	Laramie, Albany Co.	20 May 1938	not known		1		R.M.L. (#14086)
Wyoming	15 mi. NW Laramie, Albany Co.	17 June 1938	*L.* species		1		R.M.L. (#14580)
Wyoming	22 mi. SW Laramie, Albany Co.	5 July 1938	*L.* species		1		R.M.L. (#14682)
Wyoming	39 mi. N Cheyenne, Laramie Co.	16 July 1938	*L.* species		few		R.M.L. (#14894)
Wyoming	near Cheyenne, Laramie Co.	Dec 1940	*L.* species		41		Wm. B. Owen (R.M.L. #17399)
Wyoming	25 mi. SW Laramie, Albany Co.	1949	not known		X		A. B. Mickey

[1]R.M.L. - Rocky Mountain Laboratory, National Institute of Allergy and Infectious Diseases, Public Health Service, Hamilton, Montana.
[2]Plague Lab. P.H.S. - Plague Laboratory, Public Health Service.
[3]B.Y.U. - Brigham Young University, Department of Zoology and Entomology, Provo, Utah.

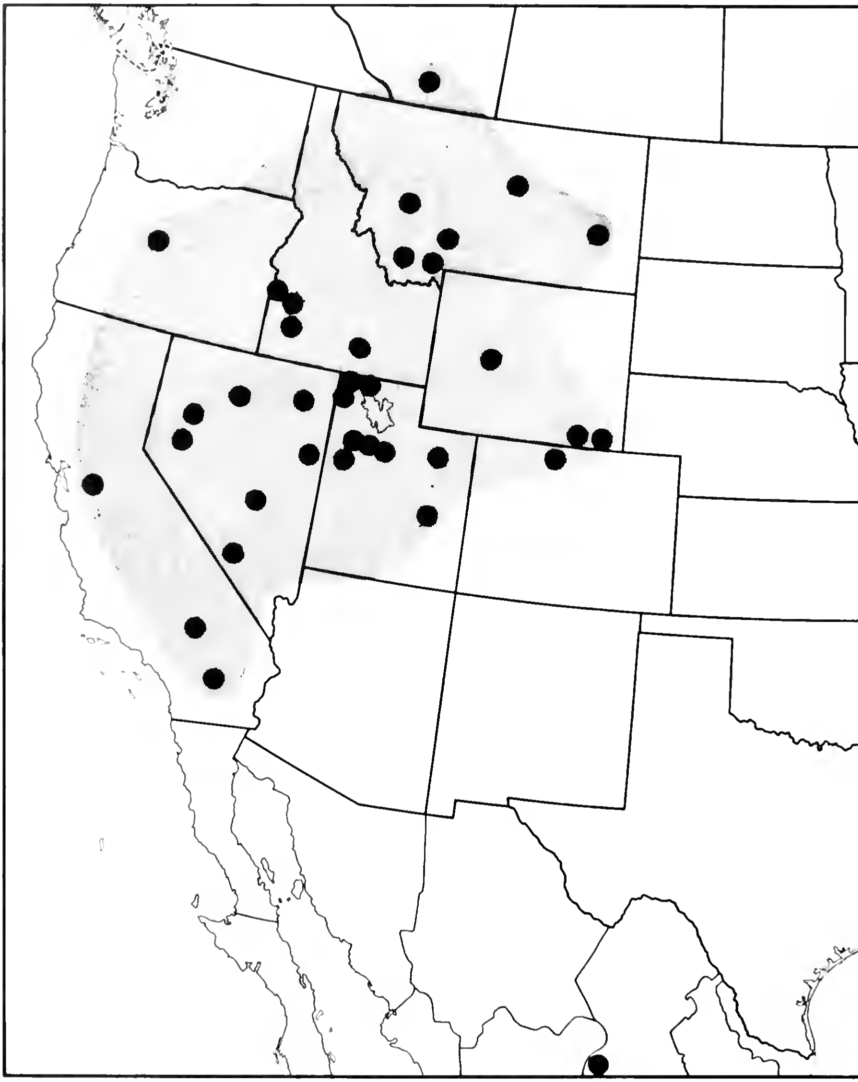

Fig. 2. Geographic distribution of *O. lagophilus* Cooley and Kohls.

the region of Montana, Wyoming, and southern Canada the tick has been collected primarily from the white-tailed jack rabbit, *L. townsendii*. A few collections from three species of *Sylvilagus* of western North America have been made throughout the known range of this tick.

Loomis (1953) reported finding adults, nymphs, and larvae at the entrance to an active rodent burrow. He stated that many small rodents may play a more significant role as hosts than has been suspected, although he did not name species.

Observations on the use of laboratory animals as suitable hosts for *O. lagophilus* were reported by Bacha (1957). He stated that although the preferred laboratory host is *L. californicus*, larvae occasionally attach to the cottontail rabbit, *Sylvilagus audubonii*, and the domestic white rabbit, *Oryctolagus cuniculus*. His attempts to infest an adult kangaroo rat (*Dipodomys ordii*), a suckling deer mouse (*Peromyscus maniculatus*), and a suckling western harvest mouse (*Reithrodontomys megalotis*) were unsuccessful. Attempts to use guinea pigs as laboratory hosts have been unsatisfactory even though in several cases larvae attached to test pigs (Hopla, 1955; Bacha, 1957).

An index of host preference for *O. lagophilus* is shown in Figure 3. This was determined by counting the number of times the parasite was collected from a given host, rather than the number of specimens found on the host.

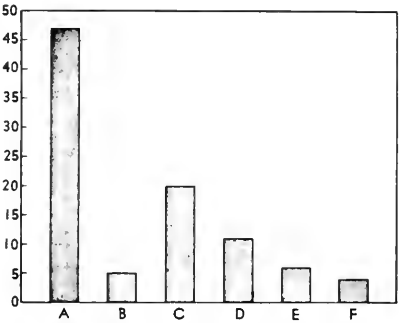

Fig. 3. Host preference of *O. lagophilus*, expressed as number of collections per host. A-*Lepus californicus*. B-*L. townsendii*. C-*L.* species (unidentified). D-*Sylvilagus* species (*S. audubonii*, *S. nuttallii*, and *S. idahoensis*). E-on ground or in rodent burrows. F-all others (*Equus asinus*, *Felis catus*, and several not known).

LIFE HISTORY

Little is known about the life history of *O. lagophilus* in nature, and only few laboratory studies have been made (Hopla, 1955; Bacha, 1957).

After emergence from the egg, the larva crawls about and seeks a suitable host or clings to low vegetation to await a passing host. It attaches to the host and feeds until fully engorged, then molts and transforms to a nymph while remaining attached to the same host. The nymph does not detach and drop from the host until it has completely engorged (Woodbury, 1955; Bacha, 1957).

Bacha (1957) observed that after the larva attaches to the host, approximately 14 to 17 days are required before it molts to a nymph. The period from the larval molt to the nymphal molt averages about 41 days (Hopla, 1955; Bacha, 1957).

Adult *O. lagophilus* lack functional mouthparts, are not parasitic, and thus do not feed. During the nymphal stage sufficient food is obtained for completion of the life cycle. After the nymphs drop from the host and molt to adults, the males and females seek each other and copulation takes place. In Bacha's experiments 6 to 29 days (average 14.6) ensued after copulation before oviposition. Hopla reported 67 days. Bacha stated that copulation of adults was essential to the production of fertile eggs but not necessary for oviposition.

Hopla found oviposition to be of the intermittent, interrupted type. In his observations all females deposited three different egg masses, except one which deposited four. Oviposition of each egg mass required about 10 days for 100 to 250 eggs per mass. He reported that by the time the larvae from one egg mass were emerging, the female was laying again. Bacha did not state whether oviposition in his experiments was of the intermittent, interrupted type, but in general his observations agree with Hopla's. The average incubation time was reported to be 15 to 18 days (Hopla, 1955; Bacha, 1957).

DISEASE TRANSMISSION POTENTIAL

Silva-Goytia and Elizondo (1952b) reported the first evidence that *O. lagophilus* might be a vector of disease. Their studies were concerned with American spotted fever (Rocky Mountain spotted fever) in what is termed the "Region of the Laguna" which is composed of the state of Coahuila and Durango, Mexico. They carried out epidemiological studies throughout this region on domestic animals and humans. In the area where spotted fever was endemic, they found about 73% of the domestic animals to be positive for complement-fixing antibodies against the rickettsial antigen. In their studies on humans they found 30% of the population in these endemic areas to have complement-fixing antibodies. In addition they were able to isolate the spotted fever rickettsiae from the blood of about 45 patients suffering from the disease. The organisms were isolated in developing chick embryos 5 days old. The rickettsiae were classified as *Dermacentroxenus rickettsi rickettsi* (= *Rickettsia rickettsii*). The isolated strains were identical to those of the Rocky Mountain spotted fever of the Bitterroot Valley in Montana.

In attempting to discover the vectors of the disease, Silva-Goytia and Elizondo collected 83 lots of ectoparasites, including soft-bodied ticks of several species. Each lot was divided into two parts, one was used for guinea pig inoculations and the other for the inoculation of 6-day old fertile chicken eggs. Three strains of spotted fever rickettsiae were isolated from the guinea pig inoculations, the fertile egg inoculations all giving negative results. Complement-fixing antibodies against the rickettsiae were found in the surviving guinea pigs of the inoculations yielding the isolated strains. These three strains were isolated from *Ornithodoros nicollei*, *Otobius lagophilus*, and *Rhipicephalus sanguineus*. The rickettsiae isolated from *O. lagophilus* were from two lots of ticks collected at Matamoros, Coahuila, Mexico. This is the first report of evidence that this tick may be naturally infected with the spotted fever organisms.

Several years later Philip, Bell, and Larson (1955), in their studies on infectious diseases of black-tailed jack rabbits in Nevada, reported that a laboratory rabbit on which a group of *O. lagophilus* from *Lepus californicus* had fed, developed a high complement-fixing titer for spotted fever. They demonstrated that this species was naturally infected with Colorado tick fever virus. They isolated one strain from this tick and proved the identity of the virus by injection of Seitz filtrates into mice, and by mouse neutralization test with known antiserum. Their attempts to find *O. lagophilus* naturally infected with tularemia, western equine encephalomyelitis, and brucellosis were unsuccessful.

In their studies on the distribution of Colorado tick fever and virus-carrying ticks, Eklund, Kohls, and Brennan (1955) isolated the virus once from *O. lagophilus* collected in northern Nevada and in northern Utah. This isolation was made by the intraperitoneal inoculation of 3-day to 4-day old mice with the ground tick material.

Several years later the workers in the University of Utah Ecological and Epizoological Research Unit at Dugway, Utah, demonstrated by laboratory experiments the capability of *O. lagophilus* as a vector and reservoir for *Pasteurella tularensis* (Vest, 1957, 1959, 1960; Rees, 1962). Several experiments were designed to determine the persistence of *P. tularensis* in these ticks. In their experiments larvae and nymphs were allowed to feed on a rabbit which had been previously infected with *P. tularensis*. The ticks subsequently became infected. They were then reared through the successive stages of development, and some were tested at various time intervals. In one such instance a female which had been reared from the larval stage harbored *P. tularensis* for 614 days. In another experiment ticks harbored the organisms for 676 days. Their experiments also indicated that *P. tularensis* infection might have had an adverse effect on *O. lagophilus*. Of 262 nymphs infected, 21% failed to molt to adults, whereas in uninfected control ticks only 11% failed. Of 103 infected females only 59% laid eggs, whereas of the control females 85% laid eggs. It was also observed that the clutch size was not more than half as large for infected females as for the controls.

In other experiments kangaroo rats were allowed to ingest adult *O. lagophilus* harboring *P. tularensis*. In all cases the rats died.

Experiments were designed to determine if transovarian transmission occurred. Eggs from infected females were tested for the presence of *P. tularensis* and some were incubated and the larvae subsequently tested. In all cases the eggs and larvae were completely free of the organisms. It was concluded from these experiments that once infected with *P. tularensis*, *O. lagophilus* remains infected for life, but is not capable of transmitting the organisms to its young.

Vest (1961) reported that over a period of three years 287 *O. lagophilus* ticks were tested for Q fever. None were found to be infected. An experiment was conducted to determine the capability of this tick to function as a reservoir and agent of transfer of Q fever. Due to technical difficulties no data were obtained (Vest, 1960).

Since *O. lagophilus* is a one-host tick, remaining attached to the same host during the larval and nymphal stages, there is little chance of its being an important vector of any disease in nature. The possibility of transovarian transmission of disease organisms has not yet been demonstrated. This tick may be a potential reservoir of diseases in nature if an animal eats an infected tick.

ANATOMICAL AND MORPHOLOGICAL OBSERVATIONS

Distinctive Generic Characters of *Otobius*. Adults and nymphs of the genus *Otobius* are distinguished from other soft-bodied ticks by the panduriform shape of the body. There is no change in the texture of the integument at the sides of the body, and the body margin is rounded. Hood and eyes are absent except in larval *O. megnini*, which has two pairs of eyes. The sexes are similar, although females are generally somewhat larger than males.

Anatomical and morphological features are distinctive for each stage in the life cycle. The integument of the adult is granulated, and the capitulum is distant from the anterior margin. The hypostome is vestigial and without denticles. The integument of the nymph is striated and spinose, and the capitulum is near the anterior margin. The hypostome is well developed with denticles. The body of the larva is oval, and the integument thin and striated. On the dorsal body surface is a dorsal plate which tapers slightly posteriorly. There are seven to ten pairs of dorsal setae usually divided into six or seven dorsolateral pairs and two or three centrally placed pairs. The ventral body surface has five pairs of setae. The hypostome is long, blunt anteriorly, and well developed with denticles throughout its entire length and in a 2/2 arrangement (Cooley and Kohls, 1944; Clifford, Kohls, and Sonenshine, 1964).

Adult Characters of *O. lagophilus*. See Figures 4, 5, 6, and 7 for illustrations of dorsal and ventral views of male and female *O. lagophilus*. The illustrations are drawn to the same scale so that accurate comparisons may be made between the male and the female, and between adults and nymphs. Most of the characters described may be seen in these illustrations. For those characters not shown, reference will be made to more detailed illustrations. Most of the following descriptions are taken from Cooley and Kohls (1940).

The body of adults is not as definitely panduriform as in *O. megnini*. It is rounded on both ends, a little constricted just behind legs IV, and widest at legs II and III. The female is generally somewhat larger than the male (Figures 4 and 6). Cooley and Kohls (1940) and Bacha (1957) made comparative measurements of adults and nymphs in order to determine comparative sizes at these two developmental stages. The respective papers may be referred to for this detailed information.

The integument is granular, with numerous circular pits on both the dorsal and ventral surfaces (Figures 4 and 5). Each pit has a single, small, central elevation with a very short fine hair on each (Figure 22). These pits are much more pronounced dorsally than ventrally. Dorsally and ventrally there is a symmetrical arrangement of integumental depressions, the

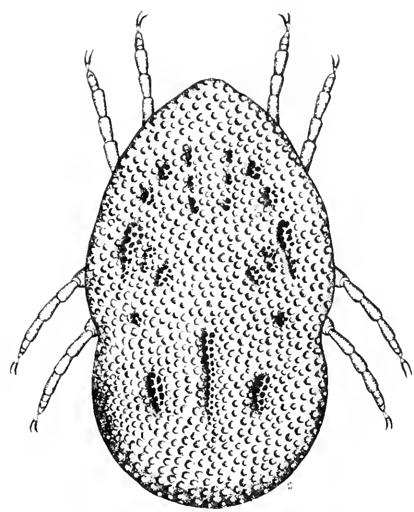

Fig. 4. Dorsal view of adult female *O. lagophilus*.

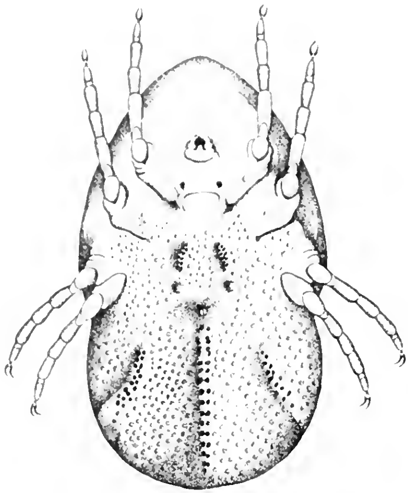

Fig. 5. Ventral view of adult female *O. lagophilus*.

floors of which are irregular, being more accentuated in the male than female (Figures 4, 5, 6, and 7.

The legs are short and moderately heavy, with few setae. On each tarsus is a moderate subapical dorsal protuberance which is most pronounced on tarsus IV (Figure 8). Coxal and supracoxal folds are present, but less obvious in well engorged specimens.

The basis capituli is very broad, short, curved, approaching a reniform shape with a con-

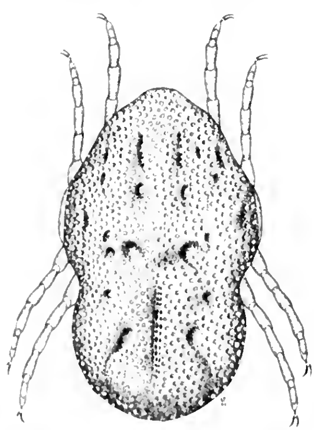

Fig. 6. Dorsal view of adult male *O. lagophilus*.

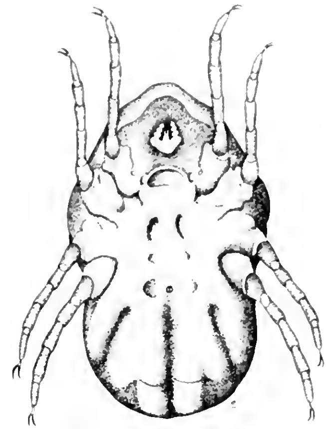

Fig. 7. Ventral view of adult male *O. lagophilus*.

vex posterior border (Figure 9). The surface of the capitulum is irregular .Ventrally on the capitulum are a pair of posthypostomal setae, two pairs of postpalpal setae, and five pairs of posteromarginal setae. The palps are moderately heavy with article I a little more swollen than the others. The palpal setae are delicate and

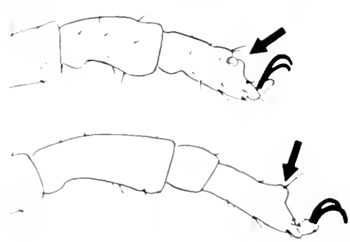

Fig. 8. Legs I and IV of adult *O. lagophilus* (from Cooley and Kohls, 1940).

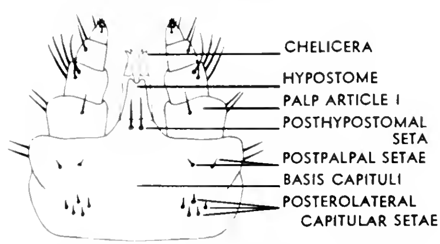

Fig. 9. Ventral view of capitulum of adult *O. lagophilus*.

long. The vestigial hypostome is bluntly rounded or bilobed and without denticles.

Other important characters are a pair of ovate spiracles with convex surfaces, located a little dorsal and posterior to the fourth pair of legs; a ventrally placed genital aperture in line with the posterior ends of coxae I; a small nearly circular anus in a posteroventral position; a short transverse postanal groove; and a faint median postanal groove.

Nymphal Characters of *O. lagophilus*. See Figures 10 and 11 for illustrations of dorsal and ventral views of the average size nymph. Figure 12 shows an unengorged nymph and Figure 13 a fully engorged specimen. All illustrations of nymphs are drawn to the same scale as the adults. It should be noted that the spines are present over the entire surface of the body and not just around the lateral margins as is shown in the illustrations.

The integument, dorsal and ventral, is smooth and shiny with fine reticulations, transverse striae, and spines. Spines are abundant and long at the anterior end, becoming smaller and sparse toward the posterior end (Figures 27 and 28). They are absent in the area surrounding the mouthparts and are more sparse on the ventral surface than on the dorsal. In our studies we observed some variation in the size and abundance of spines in different specimens; some specimens had a rather sparse distribution of small spines, whereas other specimens had many large spines over most of the body. The integumental depressions so obvious in the adults are also evident in the nymphal stage, but the symmetrical arrangement is not as apparent.

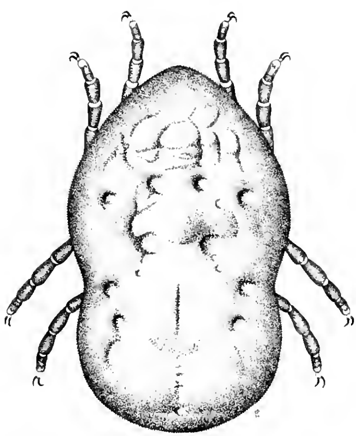

Fig. 10. Dorsal view of nymphal *O. lagophilus*.
Spines are present over entire surface of body and not just around margins as shown.

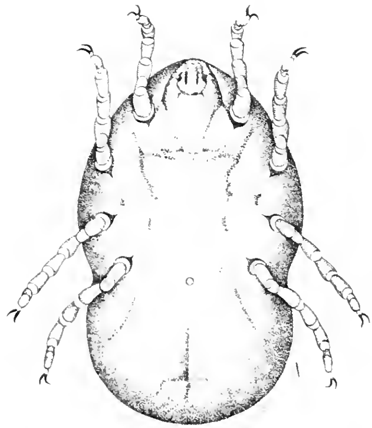

Fig. 11. Ventral view of nymphal *O. lagophilus*.
Spines are present over entire body surface and not just around margins as shown.

The legs are short and moderately heavy, with a few setae. A subapical, dorsal protuberance is distinct on tarsus IV as in the adult, but is absent or small on tarsi I, II, and III (See Figure 8). The coxae are present as inconspicuous sclerites. Coxal and supracoxal folds are faint or absent.

The capitulum is somewhat broader than long and is located in a depression formed by a circular tumescence around it (Figures 11 and 14). Located ventrally on the basis capituli are a pair of posthypostomal setae, a pair of post-

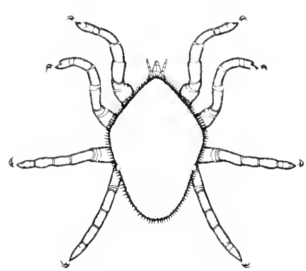

Fig. 12. Dorsal view of unengorged nymphal *O. lagophilus*.
Spines are present over entire body surface and not just around margins as shown.

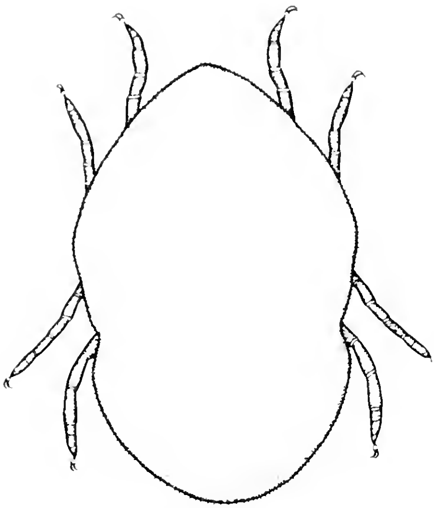

Fig. 13. Dorsal view of fully engorged nymphal *O. lagophilus*.
Spines are present over entire body surface and not just around margins as shown.

palpal setae, and three pairs of posterior central capitular setae. The palpi are moderately heavy with article I lacking a ventral swelling. Palpal setae are small and few in number. The hypostome is large, with the sides nearly parallel. The denticles are long and sharp and in a 3/3 arrangement.

Other features are a pair of circular, mildly convex spiracles in the same position as in adults (Figure 30), and a posteroventrally placed anus. The anus has no true grooves around it, but preanal and median postanal grooves are indicated

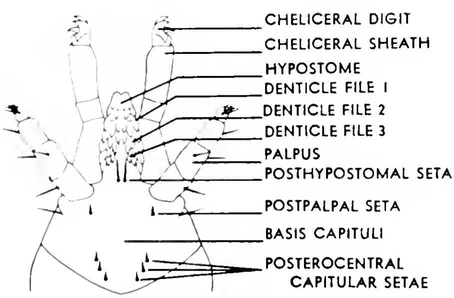

Fig. 14. Ventral view of capitulum of nymphal *O. lagophilus*.

by shallow, elongated depressions. A genital aperture is not present in the nymph.

Larval Characters of *O. lagophilus*. The following description of the larva is suggested by the studies being conducted by Clifford, Kohls and Sonenshine (Clifford, Kohls, and Sonenshine, 1964; Kohls, Sonenshine, and Clifford, in press). See Figures 15 and 16 for labeled illustrations of dorsal and ventral views of laboratory reared, unengorged larvae. Figures 17 and 18 showing dorsal and ventral views of unengorged larvae are drawn to the same scale as Figures 19 and 20, which are dorsal and ventral views of fully engorged specimens. These illustrations give a comparison of the size of unengorged with fully engorged specimens. However, these are not drawn to the same scale as are the adult and nymphal illustrations.

The integument, dorsal and ventral, is thin and striated. The dorsal plate is slightly wider anteriorly than posteriorly. Seven to nine pairs of dorsal setae are present, with five or six pairs located dorsolaterally and two pairs placed centrally. In all the specimens examined there were seven pairs of dorsal setae, five pairs located dorsolaterally and two pairs centrally. Five pairs of setae are present on the ventral body surface—three pairs of sternal setae located in the area between coxae II and III, one pair of anal setae within the confines of the anal circle, and a pair of postanal setae. In fifty specimens examined the postanal setae are absent in a majority of cases, whereas in other specimens only one or the other of the pair is present. The other four pairs of setae are present.

The three pairs of legs are long and slender, with two to eighteen setae on each segment. The coxae are not contiguous. There is a ventrally apical spur on each coxa. Pretarsi are long and slender. The legs of engorged larvae are often distorted and apparently functionless.

The capitulum is long and slender. The hypostome makes up a little over half the length of the capitulum, and the hypostome arises directly from the basis capituli and not from a median extension. On the ventral surface of the basis capituli are two pairs of posthypostomal setae—one pair just anterior to the point of attachment of the palps and another slightly larger pair posterior to the point of attachment of the palps. The palps are long and slender, each article possessing from none to nine setae. The hypostome is long, with large, sharp denticles in a 2/2 arrangement.

Spiracles and a genital opening are absent, but there is a posterior-ventrally placed anus.

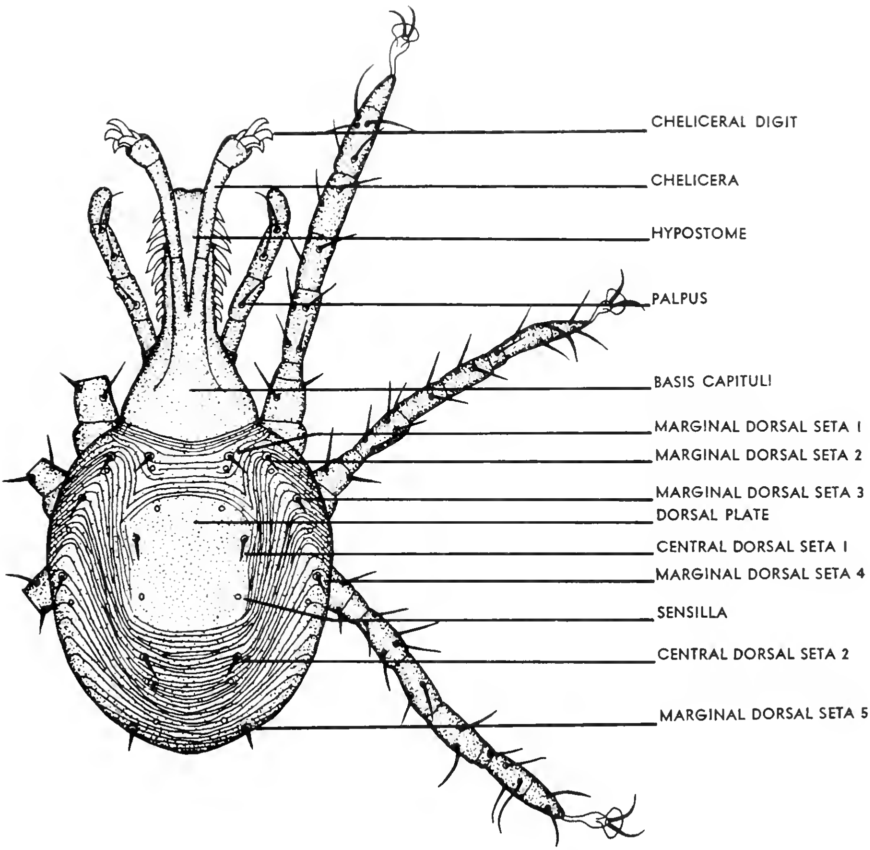

Fig. 15. Dorsal view of larval *O. lagophilus*.

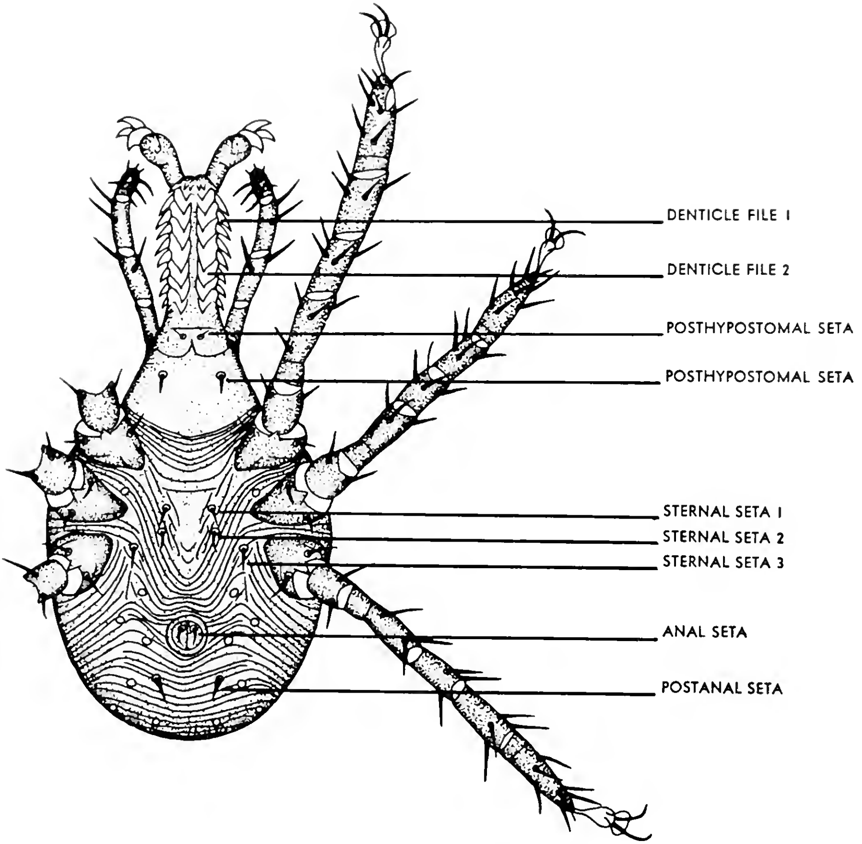

Fig. 16. Ventral view of larval O. *lagophilus*.

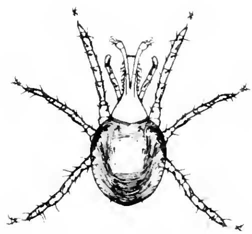

Fig. 17. Dorsal view of unengorged larval *O. lagophilus.*

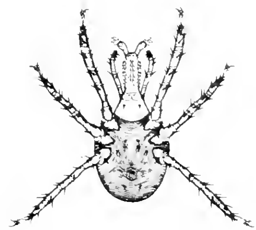

Fig. 18. Ventral view of unengorged larval *O. lagophilus.*

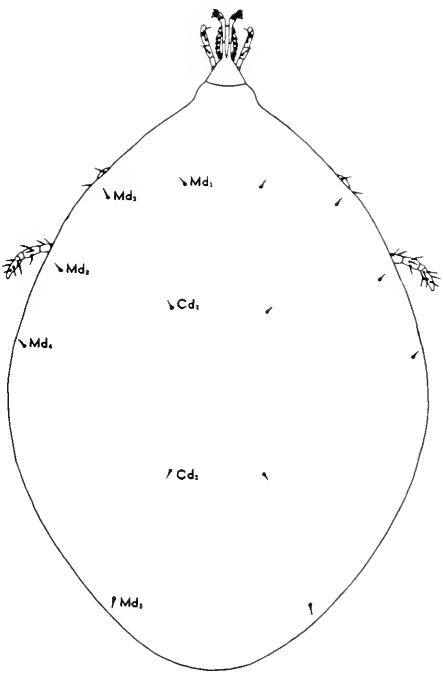

Fig. 19. Dorsal view of fully engorged larval *O. lagophilus* showing position of body setae (refer to Fig. 15).

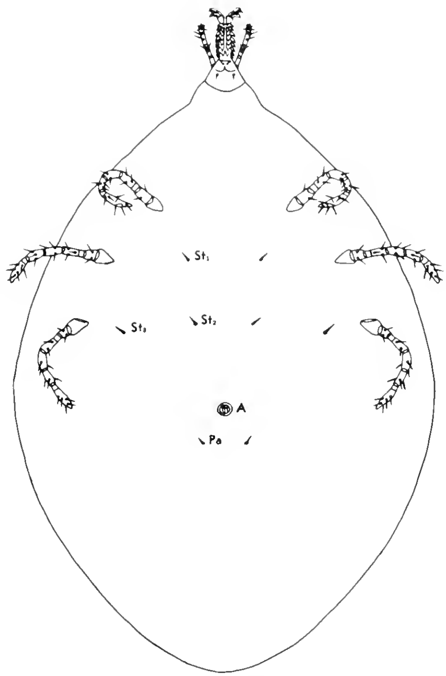

Fig. 20. Ventral view of fully engorged larval *O. lagophilus* showing position of body setae (refer to Fig. 16).

TAXONOMIC KEYS

O. lagophilus is easily separated from *O. megnini* by the following pictorial key. The key to adults and nymphs is taken largely from Cooley and Kohls (1944), and the key to the larvae has been prepared with assistance from Glen M. Kohls.

Pictorial Key for Separation of Adults

Dorsal pits separated by a distance of twice or more the diameter of one pit (Figure 21) . . . *O. megnini*

Dorsal pits separated by a distance of the diameter or less of one pit (Figure 22) . . . *O. lagophilus*

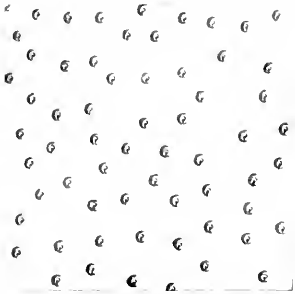

Fig. 21

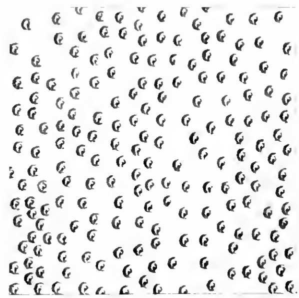

Fig. 22

Pictorial Key for Separation of Nymphs

Anterodorsal integumental spines peg-like, two or three times as thick as the more slender posterodorsal spines, and about as numerous (Figures 23 and 24); denticles near base of hypostome in 4/4 arrangement (Figure 25); apex angle of spiracles about equal to or less than the basal angles (Figure 26) . . . *O. megnini*

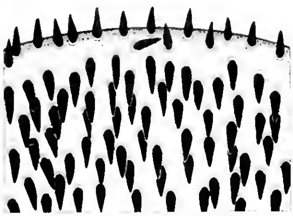

Fig. 23

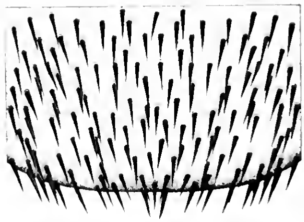

Fig. 24

Fig. 25

Fig. 26

Anterodorsal integumental spines only slightly thicker than the posterodorsal spines, but more dense in number (Figures 27 and 28); denticles near base of hypostome in 3/3 arrangement (Figure 29); apex angle of spiracles greater than the basal angles (Figure 30) .... *O. lagophilus*

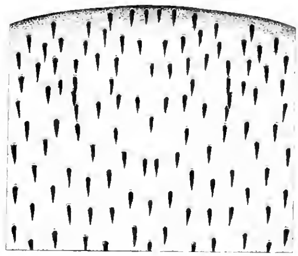

Fig. 27

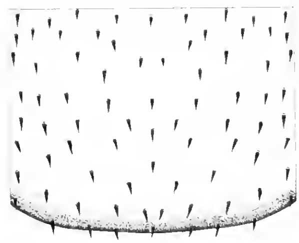

Fig. 28

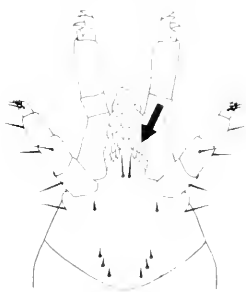

Fig. 29

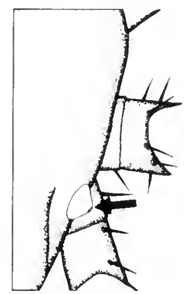

Fig. 30

PICTORIAL KEY FOR SEPARATION OF LARVAE

Two pairs of eyes present; 9 or 10 pairs of dorsal setae (Figure 31) .... *O. megnini*

Eyes absent; 7 to 9 pairs of dorsal setae (Figure 32) .... *O. lagophilus*

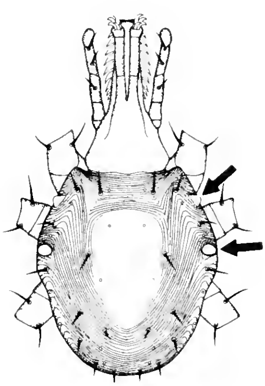

Fig. 31

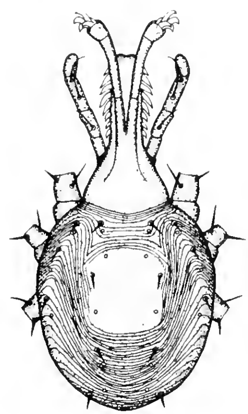

Fig. 32

SUMMARY

The principal objective of this study is to bring up to date information on geographic distribution, seasonal occurrence, and host-parasite relationship of *O. lagophilus* in western North America. Notes on life history and disease transmission potential are included.

Data and information were obtained from three sources: (1) natural history collections and field records at Brigham Young University over the past twenty years, (2) the Rocky Mountain Laboratory in Hamilton, Montana; and (3) published literature.

All available collection records are presented in a table from which information on geographic distribution, seasonal occurrence, and host-parasite relationship was extracted. *O. lagophilus* is known primarily from the arid and semiarid desert regions of western North America. To a marked extent the known distribution of this tick follows a pattern similar to that of the black-tailed jack rabbit, *Lepus californicus deserticola*, whose distribution is southern Idaho, most of Nevada, all of Utah except the eastern parts, western Arizona, and the southeastern part of California. The preferred host of *O. lagophilus* is *L. californicus deserticola*, although outside the range of this rabbit most collections have been from *L. townsendii* and *Sylvilagus* species. Nymphs have been collected from rabbits in every month of the year, with the peak season in May, June, July, and August. Since most collections have been in the nymphal stage, the peak seasons for larvae and adults are not known.

After emergence from the egg, the larva attaches to the host and feeds until fully engorged, then molts and transforms to a nymph while remaining attached to the same host. The nymph does not drop from the host until it is fully engorged and ready to molt to an adult. The adult, lacking functional mouthparts, is not parasitic and does not feed. Copulation and oviposition take place on the ground.

O. lagophilus has been reported to be naturally infected with Rocky Mountain spotted fever, Colorado tick fever, and tularemia. It has been shown to be capable of harboring the tularemia organism, *Pasteurella tularensis*, for as long as 676 days. Evidence indicates that *O. lagophilus* may be a potential reservoir of some diseases in nature, but not a direct vector in transmission from host to host.

Twenty-nine drawings of some external anatomical and morphological features in all stages of development were made as a basis for the construction of a pictorial key for the identification of species in the genus *Otobius*.

ACKNOWLEDGMENTS

Collections made throughout the western United States by various expeditions sent out from the Brigham Young University Department of Zoology and Entomology have been supplemented by gifts and loans of specimens by several institutions, organizations, and individuals. The Rocky Mountain Laboratory at Hamilton, Montana, through the courtesy of Glen M. Kohls, has been most cooperative. Dorald M. Allred of Brigham Young University supplied laboratory-reared specimens which he had cultured when a member of the University of Utah Ecological and Epizoological Research Unit at Dugway, Utah. The collections of ticks resulting from the four-year (1959-1963) A.E.C.-B.Y.U. Ecology project at the Nevada Test Site, Mercury, Nevada, are in our possession.

We wish to express appreciation to Glen M. Kohls and Dorald M. Allred for reviewing the manuscript and giving valuable suggestions.

Some of the illustrations of adults and nymphs were made by L. Douglas Hill.

Identification of specimens in our collection was confirmed by Glen M. Kohls and Carlton M. Clifford.

The Department of Zoology and Entomology, Brigham Young University, supplied laboratory space, equipment, and supplies.

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Biological Series — Vol. VI, No. 3

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FOREWORD

This is another in an extensive series of publications on the fauna of the Nevada Test Site and desert ecology resulting from studies made by the Department of Zoology and Entomology, Brigham Young University, in cooperation with the United States Atomic Energy Commission. The data reported herein are designed to furnish basic information concerning what mammals are present, where they live, and when they are active. This information is essential to an evaluation of the effects nuclear weapons testing, peaceful use of nuclear weapons, and nuclear warfare may have on mammal populations.

Dorald M. Allred, D Elden Beck, and
Clive D. Jorgensen, Project Supervisors

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MAMMALS OF THE NEVADA TEST SITE[1]

by

Clive D. Jorgensen and C. Lynn Hayward[2]

INTRODUCTION

Scientific inquiry has evolved from its earliest rather meager beginnings to a convincing sophistication. The development of our present scientific status has included numerous periods of particular emphasis, depending largely on the personal interest of the investigators, but also influenced by the scientific, social, political, and economic needs of the time. Recent scientific advances and technology have led us into an era frequently referred to as the "Atomic Age." Concurrent with the development of an understanding of atomic power and its uses are the new biological problems centered around fallout, waste disposal, nuclear war, food contamination, and technical peaceful uses of atomic energy.

In summarizing the need for ecological studies, Wolfe (1963) said:

> Now comes the Atomic Age, with its attendant new and immediate problems, not to mention those that are of a long-term nature. Problems are multiple at every level of biological organization, and in each of the seven major areas of nuclear energy effort, ecological understandings are important and immensely needed. To the timid who blanch before the nobility of biochemical and molecular biological research of the past decade; who are debating the relative merits of various biological research approaches; and who are awed by the splendor of space, the excitement of creating a primordial living system, it is appropriate to suggest that ecologists stick to their own lasts. The last assessment of experimental results in biology must be ecological, and the understanding of the environment and its working complex is likely to be essential to survival. For scientific and useful principles in replacing and juxtaposing biological material over a landscape is as inevitable as it is ecological. What greater challenge! And it is not inappropriate to remark that before the chemist tells you why birds and butterflys and fish and mammals have homing proclivities, ecological data must tell him when and where. And while this may add to ecological pride, it really emphasizes the endless need to investigate life at all stages and levels of its systematic expression.

Perhaps even more fundamental than when and where is the question of what. Frequently, biological surveys have not established an adequate listing of what is present before initiating studies of interactions between biological and other environmental factors. This report discusses what mammal species are present, when they are active, and where they would be expected at the Nevada Test Site. Answers to these questions are fundamental to understanding how nuclear weapons testing affects populations of small mammals.

Since basic ecological studies were first initiated at the Nevada Test Site (1959 to present), considerable work has been done with small mammals by the University of California, Los Angeles, and Brigham Young University. Even as this report is being prepared, continued research is under way on several aspects of the ecology of small mammals at the test site.

Three ecological factors must be considered when evaluating the effects a nuclear weapons test has on small mammals: (1) fallout and biological distribution of radionuclides, (2) initial radiation, and (3) physical effects close-in to ground zero. In each case, if one is concerned with the population, the questions of what, when, and where must be answered. Martin (1964) has summarized much of the work that has been done with respect to fallout and the biological availability of radionuclides resulting from weapons testing. The effects, or at least possible effects, of initial radiation and physical effects on small mammal populations near ground zero are being reported in another paper.

Allred, Beck and Jorgensen (1963a) discussed many aspects of the ecological distribution of all animals known at that time to occur at the test site. They identified and delineated a broad classification of biotic communities, in which the predominant vegetation was briefly discussed. The biotic communities identified by them (Larrea-Franseria, Grayia-Lycium, Coleogyne, Atriplex-Kochia, Salsola, and Pinyon-Juniper) are used as a basis in our work.

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Small mammals are frequently adapted to rather restricted ecological conditions within their distributional range (Murray, 1957, Blair, 1951). All possible habitats within a species range must be examined for an understanding of spatial distribution. As near as could be determined, most of the habitat types at the test site were sampled rather completely. The desert floor with its many modifications such as arroyos, edaphic changes, and slope was considered as the transects were established. Restricted areas around springs, buildings, and dry mountain ridges were also sampled. This extensive survey furnishes a rather complete knowledge of where each species was during the sampling period and when it was active. From this knowledge some predictions may be possible which would allow a better evaluation of test effects.

During the study of mammals, nearly 200 sampling transects and 10 grids were established, and thousands of small mammals captured. A large portion of these were simply marked and released, thus providing much of the population data presented in this report. Many were retained for study specimens, and are presently housed in the Brigham Young University Museum; others were examined for ectoparasites and discarded. Specimens were collected each month from all of the major biotic communities to determine seasonal fluctuations, mating behavior, activity cycles, etc.

Large mammals were not studied nearly so extensively. Hundreds of sight records were made, however, and many specimens collected for identification.

Data on behavior and population parameters were collected primarily because of their obvious necessity in fulfilling Brigham Young University's initial primary objective: to determine the kinds, populations, seasonal occurrences, geographic and ecologic distributions, migrations, home ranges, and related habits of native animals at the test site. For instance, the home range has long been considered important in the behavior of small mammals, but not simply because it is a population parameter which is convenient to measure. It is essential in computing densities and understanding individual interactions. Other factors such as activity and trap response also influence trapping data and must be considered when interpreting the analyzed data. These influencing factors were examined wherever possible.

The data reported here have been accumulated over the last five years and represent the work of many men. The research and analyses were supported by contracts AT(11-1)-786, AT (11-1)-1336, and AT(11-1)-1355 between the United States Atomic Energy Commission and Brigham Young University. We are particularly grateful for the cooperation between the University and the Commision which made this much needed work possible. Dorald M. Allred initiated this work at the Nevada Test Site, and we are especially grateful for his foresight and courage in beginning these investigations. Although many men and women assisted in gathering and analyzing these data and we are appreciative of them all, we are particularly grateful to Gerald L. Richards, Merlin L. Killpack and Arnold M. Orton, who gathered most of the field data, and Linda Terry, who assisted in processing the field data for computer analysis.

ACCOUNTS OF THE SPECIES

METHODS

Although several trapping techniques and designs were used to establish the species which were present and many others tried, the two most used were (1) continuous trapping of 624 are (15.6 acre) grids and (2) double line transects (Allred, Beck and Jorgensen, 1963a). Ten grids were placed among the distinct biotic communities, and 136 double line transects were established primarily within the ecotone areas between these communities.

The grids were maintained active for several months each (up to 29) and trapped for three consecutive days each month. Small mammals from these grids (except for unusual species or specimens) were marked and released. The double-line transects were equipped with Museum Special traps and were activated for three consecutive days (see Allred, Beck and Jorgensen, 1963a for details of each trapping design.)

Large mammals were routinely identified with sight observations of the animals themselves and their readily identifiable signs, e.g. feces, tracks, etc., though specimens were collected for almost all species. Some species were routinely recorded from vehicle kills on the highways (e.g. Black-tailed Jack Rabbit) while others

were recorded only after they had been killed by vehicles or predators.

All field records were accompanied by observations of the plant community so that the spatial distributions and biotic communities could be coordinated for each species. Most of the specimens collected which were not marked and released were retained for further studies and many (466) were prepared for museum specimens. These data are presented in this section.

Results

Sorex tenellus Merriam
Inyo Shrew

Three specimens: August 12, 21; April 9.

All specimens were collected from the Pinyon-Juniper community (Jorgensen and Hayward, 1963).

Sorex merriami leucogenys Osgood
Merriam's Shrew

One specimen: October 31.

This specimen was collected from the Pinyon-Juniper community (Jorgensen and Hayward, 1963).

Notiosorex crawfordi crawfordi (Coues)
Desert Shrew

One specimen: October 11.

This specimen was collected from a rather mesic canyon of the west slope of Ranger Mountain.

Myotis californicus stephensi Dalquest
California Myotis

Five specimens: August 3; November 28.

For many years this race was known by the subspecific name *pallidus*. Dalquest (1946) found *pallidus* to be preoccupied and proposed the new name *stephensi* for this distinctly paler inland desert race.

All specimens were collected from artificial caves and were not associated with any particular biotic community.

Pipistrellus hesperus hesperus (H. Allen)
Western Pipistrella

Fifteen specimens: from May to October.

These small bats were probably the most numerous of all bats at the test site. Observed flying in areas where insects were attracted by either lights or water, they were most abundant during the early evening. However, some were observed for most of the night.

Corynorhinus townsendii pallescens Miller
Townsend's Big-eared Bat

Five specimens: October 22; November 28.

The races of this species seem to be separated exclusively on the basis of color. The specimens from the test site are somewhat darker than specimens of *pallescens* from southern California but decidedly paler than *intermedius*. Hall (1946) comments that this is also the case with the Nevada specimens he examined.

This species was collected entirely from the vicinity of standing water.

Antrozous pallidus pallidus (LeConte)
Pallid Bat

Four specimens: May 1; July 1, 8; August 11.

On the basis of size (average length of 3 females and 1 male, 107.7 mm) the test site specimens are closer to typical *pallidus* than to *pacificus*.

This species was observed and collected primarily from the vicinity of standing water. One was collected by Killpack and Goates (1963) in a Museum Special trap set for small mammals.

Sylvilagus nuttallii grangeri (J. A. Allen)
Nuttall's Cottontail (Fig. 10)

One specimen: November 21.

This secretive species was observed primarily in the Pinyon-Juniper community, and never on the valley floors. *Sylvilagus audubonii* and *nuttallii* overlapped their ranges at the bases of mountains which were topped with Pinyon and Juniper. Although few were collected and only one preserved, they were not uncommon in their preferred community. This species seemed to be much more secretive and shy than *audubonii*.

Sylvilagus audubonii arizonae (J. A. Allen)
Desert Cottontail (Fig. 10)

Eight specimens: August 4, 25; November 1, 22, 28.

This species usually occupied shelters provided by abandoned structures, of which there are many scattered throughout the test site. They were also found inhabiting the natural shelter of rock outcrops and dense cover of sagebrush. Collections and observations were made from Larrea-Franseria, Grayia-Lycium, Coleogyne,

Salsola, and Pinyon-Juniper communities, although it was probably the shelter of abandoned structures in these areas that attracted them.

Lepus californicus deserticola Mearns
Black-tailed Jack Rabbit (Fig. 9)

One specimen: January 9

This wary species was observed and collected in all the biotic communities as well as the transition areas between. On several occasions large numbers were attracted to small mammal study grids where they robbed the traps of their bait (Jorgensen, 1962). They were observed and collected from Larrea-Franseria, Grayia-Lycium, Coleogyne, Atriplex-Kochia, Salsola, and Pinyon-Juniper.

Lepus californicus texianus Waterhouse
Black-tailed Jack Rabbit

About 500 specimens of this subspecies purchased from a commercial supplier in Fort Sumner, New Mexico, were released at the test site during the first part of April, 1959 by personnel from the University of California, Los Angeles (personal communication from Page Hayden, December 12, 1961). Several specimens were captured a few days later, after which the project was discontinued. The last specimen was seen at Jackass Flats, july 6, 1959.

Eutamias dorsalis grinnelli Burt
Cliff Chipmunk (Fig. 11)

Twenty-six specimens: April 26, 27; August 1; September 14, 16; November 29.

Specimens of *dorsalis* from the Wasatch Mountains of central Utah were somewhat larger in nearly all measurements taken when compared with the test site material. The lesser inflation of the braincase ascribed to *grinnelli* by Hall (1946) when compared with *utahensis* is not evident either by general appearance or by measurement (Table 1). However, the paler color of *grinnelli* both in bright summer pelage and in the early spring dull phase is evident when compared with the series of specimens from Utah. This lighter color seems to be due to more white tipped hairs on the dorsum. Striping is fairly distinct in summer specimens, with the lateral white stripes being especially evident. The bright reddish sides are also conspicuous in the summer. A series of specimens taken in late April had not yet lost the dull winter pelage.

This species was observed and collected almost entirely from the Pinyon-Juniper commuity, being observed only sparsely in areas where the upper bajada meets the base of mountains containing Pinyon and Juniper.

Ammospermophilus leucurus leucurus (Merriam)
White-tailed Antelope Squirrel (Fig. 8)

Nineteen specimens: March 9; July 11; August 24, 26, September 22; November 6, 19.

Along with the jack rabbit this was the most conspicuous species observed during the daytime. Specimens were observed and collected from Larrea-Franseria, Grayia-Lycium, Coleogyne, Atriplex-Kochia, Salsola, and Pinyon-Juniper, as well as in the unclassified areas and on the dry mountain ranges, but they were most abundant in the valleys.

Spermophilus townsendii mollis Kennicott
Townsend's Ground Squirrel (Fig. 12)

Three specimens: March 4; May 24, 26.

This species was not abundant at the test site and was collected only from Larrea-Franseria and Atriplex-Kochia communities.

Spermophilus variegatus robustus (Durrant and Hansen)
Rock Squirrel (Fig. 12)

Seven specimens: April 26, 27; May 23, 24; June 29.

According to Durrant and Hansen (1954) the Nevada Test Site lies in an area between the ranges of S. *v. utah* and S. *v. robustus*. Our specimens seem to be intergrades but appear closer to *robustus*. We failed to find the larger skull in our specimens that is characteristic of *robustus*. However, the flaring nasals, narrower behind, are evident in some of our specimens. Also the extension of the nasals behind the fronto-premaxillary suture is rather evident. Other skull characters for *robustus* given by Durrant and Hansen were not consistently evident in the test site specimens. With the exception of one specimen, our series is more yellowish rather than reddish on the back when compared with the most extremely bicolored specimens from Utah. In our specimens the heads are often paler and the shoulder bands grayer than the Utah material.

This species was observed and collected only from the heavily wooded Pinyon-Juniper community.

Table 1. Comparative measurements of adult *Eutamias dorsalis* from the Nevada Test Site and central Utah.

Nevada Test Site Series *E. d. grinnelli*

	Museum Number	Total length	Tail length	Foot length	Greatest Length of Skull	Zygomatic breadth	Cranial breadth	Least interorbital breadth	Nasal length
Male									
	4457	212	91	31	34.1	19.1	16.2	7.4	10.5
	4458	207	90	31	34.0	18.9	16.0	7.9	10.5
	4460	210	90	31	33.5	18.8	15.8	8.3	10.3
	4462	200	82	31	33.8	18.8	15.7	8.1	10.0
	4175	208	92	31	34.0	19.3	16.3	8.9	10.3
Female									
	4459	205	77	31	33.2	18.7	16.0	8.3	10.3
	4461	213	89	30	33.9	19.2	15.8	8.5	10.1
	4174	205	96	32	34.0	19.1	16.2	8.4	10.0
Avg		207.5	89.8	31.0	33.8	18.9	16.0	8.6	10.2

Utah Series *E. d. utahensis*

	Museum Number	Total length	Tail length	Foot length	Greatest length of skull	Zygomatic breadth	Cranial breadth	Least interorbital breadth	Nasal length
Male									
	1907	204	87	31	34.9	19.3	16.3	8.3	10.2
	2102	225	115	32	35.8	19.2	16.5	8.9	10.7
	886	227	83	32	34.9	19.3	15.9	8.7	11.0
	1899	220	100	32	35.3	19.7	16.7	9.2	10.5
Female									
	1898	210	96	32	35.1	19.2	15.8	8.2	10.7
	1904	213	94	31	35.6	19.7	16.7	8.9	10.6
	1900	210	100	32	34.5	19.1	14.9	8.0	10.7
	2833	210	100	32	35.6	20.2	16.6	8.9	11.6
Avg		214.8	96.8	31.7	35.2	19.4	16.3	8.1	10.7

Spermophilus tereticaudus tereticaudus Baird
Round-tailed Ground Squirrel (Fig. 12)

Two specimens: July 16, August 9.

This squirrel was collected from Larrea-Franseria only.

Thomomys umbrinus nanus Hall
Southern Pocket Gopher (Fig. 10)

Sixteen specimens: January 26, February 16, March 7, 16, 17, 22, 26, 28, June 16; November 6, December 15.

Our specimens agree rather well in skull measurements with those of the smaller race *nanus* as described by Hall (1932, 1946). Our male specimens measure slightly larger both in body and skull than those measured by Hall; however, our females are almost identical, especially in skull measurements (Table 2). The test site specimens also exhibit the darker than cinnamonbuff and black postauricular patch mentioned by Hall. The type locality for *nanus* is given as 5.5 miles northwest of Whiterock Spring, Nye County, Nevada.

This species was collected from the valley floors most frequently, although some were found living among the rushes at Cane Springs, where they constructed an extensive system of runways. Burrows were more numerous in areas with loose soil, particularly in the Larrea-Franseria (*Lycium pallidum* association) community in Frenchman Flat. They were collected from Larrea-Franseria, Grayia-Lycium, and Atriplex-Kochia communities.

Perognathus formosus mohavensis Huey
Long-tailed Pocket Mouse (Fig. 4)

Twenty-three specimens: March 10, July 13, September 18, 21, 27.

On geographical grounds the test site population of *formosus* falls within the area occupied by the subspecies *mohavensis* (Hall, 1946, Hall and Kelson, 1959). Compared with near topotypes of *P.f. formosus* from Washington County, Utah, skull differences are difficult to detect except that the Nevada specimens (adults) do have a slightly more inflated tympanic bulla. According to Huey (1938) in his original description of *mohavensis* this race is supposed to have less inflated bullae than *formosus*, but Durrant (1952) found the opposite to be the case. Our observations tend to confirm Durrant's analysis provided we are actually dealing with Huey's race. From the standpoint of color, most of our specimens possess the lighter quality ascribed to *mohavensis* but a few specimens are almost identical with topotypes of *formosus* in this respect. Since we have not had an opportunity to compare Huey's type material with our series, we are still uncertain of the possible intergradation at the test site.

This species was collected from all of the biotic communities, although more abundant in some than others. On the valley floors, it seemed to prefer deep soils with small rocks scattered throughout. It was also one of the few found to inhabit the desert pavement. Specimens were collected from Larrea-Franseria, Grayia-Lycium, Coleogyne, Atriplex-Kochia, Salsola, Pinyon-Juniper, and the dry mountain ranges.

Table 2. Measurements of *Thomomys umbrinus* from the test site.

Museum number	Basilar length	Zygomatic breadth	Least interorbital breadth	Mastoidal breadth	Nasal length	Total length	Tail length	Foot length
Female								
4068	28.3	20.2	6.5	17.3	11.1	185	55	26
4480	27.2	18.6	6.3	16.7	10.5	176	66	24
4161	28.9	20.8	6.6	17.7	10.5	205	57	25
4063	28.8	19.8	6.4	17.9	11.3	195	48	26
Avg	28.3	19.8	6.5	17.4	10.8	190	56	25
Male								
4482	30.0	21.6	6.8	18.4	11.8	200	65	25
4064	31.7	23.0	6.5	19.7	12.5	227	70	26
4066	31.2	22.8	6.5	18.6	13.5	230	66	28
4067	28.2	20.5	6.6	17.2	12.5	185	55	25
4065	28.6	20.2	7.1	17.7	11.6	197	70	27
Avg	29.9	21.6	6.7	18.3	12.1	208	65	26

Perognathus parvus olivaceus Merriam
Great Basin Pocket Mouse (Fig. 11)

Sixteen specimens: March 25; June 21; August 1; September 16.

The community distribution of this species was difficult to determine because of their sparcity and the conditions under which they were collected. Generally, they were most frequently collected in Coleogyne and Pinyon-Juniper communities, although one of the highest populations observed was in a Gravia-Lycium community which had been denuded by nuclear weapons testing about four years earlier. Collections were also made in Kawich Valley, north of the test site, which is more typical of Great Basin vegetation. They were collected from Larrea-Franseria, Grayia-Lycium, Coleogyne, Salsola, Pinyon-Juniper, and the dry mountain ranges. They appeared to be scattered in low densities throughout the entire test site, but concentrated in only a few.

Perognathus longimembris (Coues)
Little Pocket Mouse (Fig. 2)

Thirty-one specimens: March 15, 29; April 7, 16, 27; June 14; July 8, 9; August 3, 4, 20.

Although we have a large series of specimens of *P. longimembris* from the Nevada Test Site, their subspecific status is not clear. Their generally smaller measurements would indicate that they come closer to *panamintinus* of eastern California and western Nevada, but there may be some intergradation especially in the lower valleys with *virginis*, named orginally from southwestern Utah by Huey (1938).

This species was collected from all biotic communities except Pinyon-Juniper. They seemed to prefer soils which were relatively deep but over-laid with small rocks. They were collected from Larrea-Franseria, Grayia-Lycium, Coleogyne, Atriplex-Kochia, and Salsola communities as well as the marginal areas between dry mountains and the upper bajadas.

Microdipodops megacephalus sabulonis Hall
Dark Kangaroo Mouse

Three specimens: April 25.

The few specimens at our disposal seem to fit well the description given by Hall (1946) for the race *sabulonis*. The darker color, longer tail, and plumbeous rather than white bases of the ventral hairs and smaller skull distinguish it from the races *paululus* and *megacephalus* that have adjoining ranges.

Although we expected to collect this species on the test site, it was collected only from an *Artemisia tridentata* community in Kawich Valley north of the test site.

Dipodomys ordii monoensis (Grinnell)
Ord's Kangaroo Rat (Fig. 1)

Ten specimens: January 22; March 10; June 21; October 3, 7.

The Nevada Test Site lies in an area where the *D. ordii* races *monoensis* and *fetosus* are likely to overlap. Compared with a series of *fetosus* from western Millard County, Utah, the test site specimens have longer tails and feet, but the size of the skulls is about the same. According to Hall (1946) *monoensis* is smaller than *fetosus* with respect to the above measurements but the difference is not great. Comparing specimens in bright pelage, taken in October and September, the test site series is decidedly more reddish on the whole but individual specimens can be selected that match closely with the Utah series (Table 3). This color difference seems to be the best justification for assigning our specimens to the race *monoensis*.

Table 3. Comparative measurements of adult *Dipodomys ordii* from the Nevada Test Site and Millard Co., Utah.

Nevada Test Site Series *D. o. monoensis*					Millard Co., Utah Series *D. o. fetosus*				
Museum number	Tail length	Foot length	Basal length	Greatest breadth	Museum number	Tail length	Foot length	Basal length	Greatest breadth
4477	144	42	26.1	23.7	2674	136	40	26.0	23.4
4478	135	41	25.6	23.5	2677	134	39	26.1	23.1
4075	142	39	25.1	23.4	2675	133	37	26.1	23.3
4076	145	40	26.1	23.7	2673	141	39	26.8	24.0
4036	133	40	26.3	23.5	2681	129	40	25.7	23.8
4037	130	38	25.8	23.3	2676	135	40	26.9	23.7
4038	134	38	26.8	23.2	1474	132	39	26.0	23.2
4039	135	41	26.2	23.8					
Avg	137.2	39.8	26.0	23.6		134.3	36.3	26.2	23.5

The community distribution of this species was difficult to determine since it was widely collected but never especially abundantly. It was most frequently collected from areas disturbed by nuclear weapons testing. It was collected from Larrea-Franseria, Grayia-Lycium, Coleogyne, Salsola, and several marginal areas adjacent to these communities.

Dipodomys microps occidentalis Hall and Dale
Chisel-toothed Kangaroo Rat (Fig. 6)

Twenty-nine specimens: March 4, 15, 16, July 11; August 21, 27, September 4, 10, 16, 21; October 3, 8, November 5, 11, 13.

In measurements the Nevada Test Site series approaches nearer to the smaller *occidentalis* than *centralis* (Hall, 1946), both with respect to external body measurements and several skull measurements although the skull measurements are not strikingly different in most instances (Table 4). We have seen no specimens of *centralis* for comparison of color.

This species was the most widely distributed kangaroo rat at the test site. It was collected from Larrea-Franseria, Grayia-Lycium, Coleogyne, Atriplex-Kochia, Salsola, and the dry mountain ranges, but it was rather rare in the Larrea-Franseria.

Dipodomys merriami merriami Mearns
Merriam's Kangaroo Rat (Fig. 7)

Twenty-eight specimens: February 26; March 10; July 11; August 2, 18, 20, 21; September 4, 10; November 17, 28.

Hall (1946) recognizes only the one subspecies (*merriami*) from Nevada. While there appears to be a gradient in certain measurements from south to north, particularly tail length, no clear-cut races can be recognized, according to him.

This species was collected from all of the communities in the valleys, although usually least abundantly in the Coleogyne and Atriplex-Kochia. In one case, Mid-Valley, it was the most abundant species of kangaroo rat in *Artemisia tridentata* stands and virtually absent from adjacent *Coleogyne* stands. They were collected from Larrea-Franseria, Grayia-Lycium, Coleogyne, Atriplex-Kochia, Salsola, and foothills surrounding the valleys.

Dipodomys deserti deserti Stephens
Desert Kangaroo Rat (Fig. 1)

Twenty-one specimens: February 3; March 18, 23, July 31, August 2, 3, 25.

Hall (1946) was unable to find sufficient variation in the Nevada population of *deserti* to justify subspecific names and therefore included all of his material in the race *deserti*.

This species had a very limited distribution at the test site. It was found entirely in areas which showed some evidence of disturbance, particularly man-made disturbance, and was most abundant in Frenchman Flat on the playa where dikes had been constructed to divert water. Wherever found, they were always in loose and/or sandy soil. Specimens were collected from Larrea-Franseria and Salsola communities.

Reithrodontomys megalotis megalotis (Baird)
Western Harvest Mouse (Fig. 11)

Five specimens: February 16; March 9, 25; October 1; November 13.

This race is the only one known for Nevada and has an extensive range over the greater part of the intermountain west.

This species was collected only from Salsola communities. It appeared to be uncommon, which may account for our failure to collect it from other communities.

Table 4. Measurements of *Dipodomys microps* from the test site (all males).

Museum number	Body length	Tail length	Foot length	Basal length	Nasal length	Greatest breadth	Maxillary breadth	Interorbital breadth
4016	114	155	42	27.0	12.8	24.8	20.2	12.6
4017	119	127	42	27.7	13.0	24.5	19.6	12.1
4019	107	156	42	26.7	12.8	23.6	19.1	11.6
4020	124	162	42	28.1	13.1	23.4	19.4	12.0
4022	114	152	41	27.2	12.6	23.2	18.8	11.4
4024	113	151	42	26.4	12.2	23.1	18.3	11.7
4028	117	159	41	27.1		23.2	19.4	11.9
Avg	115	152	41.7	27.2	12.7	23.7	19.2	11.9

Peromyscus crinitus stephensi Mearns
Canyon Mouse (Fig. 3)

Twenty-seven specimens: March 4; June 13; July 2, 13, 27; August 2, 3, 20; October 3; November 8, 28.

Although collected in only small numbers, this species was universally distributed. It was most frequently collected from areas in the vicinity of rocky outcrops, and was actually abundant in some of the foothills. It was collected in Larrea-Franseria, Grayia-Lycium, Coloegyne, Atriplex-Kochia, Salsola, Pinyon-Juniper, and the dry mountain ranges.

Peromyscus eremicus eremicus (Baird)
Cactus Mouse (Fig. 12)

Seven specimens: March 14; February 16.

This species was collected primarily around springs. A small endemic population inhabited the area in the immediate vicinity of Cane Springs. They frequently used the runways constructed by *T. umbrinus* at the water's edge.

Peromyscus maniculatus sonoriensis (LeConte)
Deer Mouse (Fig. 13)

Twenty-eight specimens: March 25; April 7, 27, 28; August 1, 20; November 28, 29.

This species was collected from all communities, although it seemed to be most abundant in Pinyon-Juniper.

Peromyscus truei truei (Shufeldt)
Piñon Mouse (Fig. 13)

Six specimens: March 29; April 26; May 19; June 6; July 6.

This species was trapped almost entirely from the Pinyon-Juniper community and the foothills adjacent to it. One specimen was collected in Grayia-Lycium, but near a rocky outcrop at the base of a mountain on which Pinyon-Juniper occurred.

Onychomys torridus longicaudus Merriam
Southern Grasshopper Mouse (Fig. 5)

Fourteen specimens: June 14, 16; July 11; September 5, 11; October 1, 5, 27; November 1.

This species was trapped from all communities, although it was apparently not abundant anywhere.

Neotoma lepida lepida Thomas
Desert Wood Rat (Fig. 1)

Seventy-nine specimens: January; June; July; August; September; October; November; December.

All of the specimens for which the baculum was saved possessed the long, slender, and curved structure characteristic of *lepida* (Burt and Barkalow, 1942). The characteristic of all the hairs on the venter being plumbeous at the base as given frequently in descriptions and keys is by no means true in many specimens of *lepida*, not only in the test site area, but elsewhere. The amount of pure white ventral hairs varies in the test site material from a small pectoral spot to an extension onto the throat and even the chin. It frequently also extends well down onto the belly.

As one would expect this species was collected most abundantly in the mountainous areas where its shelters could be built in the protection of the rocks. They were also found on the valley floors in areas of extensive *Yucca* on the bajada. On occasion, they were collected some distance from any apparent shelters or areas suitable for shelters. This led us to suspect they moved over the valley floors more frequently than might be expected in view of their usual nesting habits. They were collected from Larrea-Franseria, Grayia-Lycium, Coleogyne, Atriplex-Kochia, Salsola, Pinyon-Juniper and dry mountain ranges.

Lagurus curtatus curtatus (Cope)
Sagebrush Vole (Fig. 13)

One specimen: April 12.

The single specimen is placed in the subspecies *curtatus* entirely on a geographical basis. Intergradation between *curtatus* and *intermedius* occurs in the general area of the test site (Hall, 1946).

The specimen was collected from Pinyon-Juniper, but may also be present in *Artemisia tridentata* which coinhabits certain areas with Pinyon and Juniper.

Erethizon dorsatum (Linnaeus)
Porcupine

Although scat of this species was occasionally seen in Pinyon-Juniper, the only specimen recorded was killed on a highway in Larrea-Franseria, about 20 miles from the nearest Pinyon or Juniper.

Canis latrans Say
Coyote (Fig. 14)

Four specimens: February 8; August 17; November 22, December 8.

The Nevada Test Site lies in an area of intergradation of *C. l. lestes* and *C. l. mearnsi* (Hall, 1946). It seems evident that this area of intergradation is very wide and we have insufficient comparative material to assign a subspecific name.

Either signs were seen or specimens collected in all of the communities.

Vulpes macrotis Merriam
Kit Fox (Fig. 14)

Seven specimens: January 19; February 16; September 14; December 18, 22, 30.

Both the races *nevadensis* and *arsipus* are listed for Nye County by Hall (1946). He stated that *nevadensis* differs from *arsipus* in that it has "black instead of brown or grayish upper lips, dark instead of light-colored forehead and usually black instead of always brown tip on tail." We are unable to see any color variations in our material that would indicate any racial difference between the test site material and specimens from farther north in the Great Basin which were assigned by Hall to the race *nevadensis*. The possible effect of tanning on colorations complicates adequate comparisons. Comparison of skulls which appeared to be of about the same age indicated that in most cases the braincase in the more northern Great Basin specimens tends to be more inflated than in those from the test site, although this was not always the case. Judging from the material at hand, it would seem that if there is justification for the recognition of two geographical races the test site population is intermediate between them. We therefore hesitate to assign it a subspecific name.

Kit foxes were unusually abundant in many areas and signs were observed in Larrea-Franseria, Grayia-Lycium, Atriplex-Kochia, Salsola, and the foothills surrounding the valleys.

Bassariscus astutus nevadensis Miller
Ringtail

One specimen: September 22.

This specimen was collected from Pinyon-Juniper.

Mustela frenata nevadensis Hall
Long-tailed Weasel

One specimen: May 15.

This species was collected only once, after one had been killed on a highway in Grayia-Lycium. It was killed only a short distance from a spring with rather dense shrubby vegetation, and this rather than the open desert floor was suspected to be its habitat.

Taxidea taxus (Schreber)
Badger (Fig. 14)

Four specimens: June 30; July 9, 16, 13.

Our specimens appear to be intergrades between *T. t. taxus* and *T. t. berlandieri*. One adult skull suitable for measurements was narrower across the zygomatic arches (81 mm) and across the mastoids (77.3 mm) than specimens of *T. t. taxus* from central Utah. In all of the test site specimens the white dorsal stripe extends well back to the shoulders and is decidedly longer than that of central Utah specimens. This stripe never extended anywhere near as far back as the base of the tail as it is supposed to do in some individuals of *berlandieri*.

Badgers seemed to appear almost anywhere in the valleys, but were not observed or collected from the mountainous areas. They were collected or recorded from Larrea-Franseria, Grayia-Lycium, Coleogyne, Atriplex-Kochia, and Salsola.

Spilogale gracilis Merriam
Western Spotted Skunk

On a geographical basis the spotted skunks of the test site might be either *S. g. gracilis* or *S. g. saxatilis;* or both subspecies might also be present. Without specimens it is not possible to identify the subspecies.

Felis concolor kaibabensis Nelson and Goldman
Mountain Lion

Sight records were made entirely from the mountainous areas and the Pinyon-Juniper community. No specimens were collected.

Lynx rufus baileyi Merriam
Bobcat

One specimen: July.

On the basis of paler color, smaller size, and smaller skull, the specimen available to us appears to be the race *baileyi* rather than *pallescens*.

The bobcat was observed primarily on the upper bajada, although it was also sighted on the valley floor and mountainous areas. It was sighted and/or collected from Larrea-Franseria, Grayia-Lycium, Coleogyne, and the mountainous areas. Though not seen in the Pinyon-Juniper, it is assumed to be present.

Dama hemionus hemionus (Rafinesque)
Mule Deer

Although this species was occasionally sighted on the valley floor and upper bajadas, it inhabited primarily the Pinyon-Juniper community or mountainous areas which were capped with Pinyon and Juniper.

Ovis canadensis nelsoni Merriam
Mountain Sheep

Mountain sheep were never observed or collected from the test site, but they were observed in the mountains around it. Also, scat believed to belong to mountain sheep was frequently seen among the low, dry mountains east of Frenchman Flat. It is very likely that they occasionally enter the test site when crossing from one mountain range to another, particularly in the winter and spring months when water is more plentiful.

Equus caballus
Horse

Horses have been rather abundant at the test site in former years. At the present, only a few small bands inhabit the mountains on the west side of the test site. They are frequently seen near the several springs, e.g. Cane Springs, Whiterock Spring, and Tippipah Spring.

Bos taurus
Cow

Cattle are maintained by the Atomic Energy Commission and are found grazing throughout the test site. Water is supplied, thus allowing them to spend rather long periods of time on the valley floors.

ACTIVITY AND BEHAVIOR

Activity is a term which has been used many different ways and determined with a rather wide variety of methods. It is frequently difficult to interpret because of the difficulty in isolating the influence exerted on the results by the method of sampling or measuring. If this influence is not understood, the investigator could form inferences and possibly conclusions concerning the populations that are in error. Evidences of activity in our studies are based entirely on the trapping data and are in every case subject to the influence the traps themselves may have had on the animal's behavior. Our conclusions are necessarily drawn with these limitations in mind.

Data will be presented concerning the activity of individuals as well as the activity of the population; however, only certain species are discussed with respect to each phase of activity. Since many species were not present in our samples, data concerning their activity simply are not available.

DAILY ACTIVITY

Ecological investigations of the fauna at the Nevada Test Site have resulted in considerable data concerning the activity of *A. leucurus, P. longimembris, D. ordii, D. microps*, and *D. merriami*. This section discusses some aspects of daily activity and activity fluctuations of these species relative to seasons, meteorological conditions, sex ratios, movement, and competition.

Daily activity curves have been demonstrated for several species in North America: *D. merriami* (Reynolds, 1960), *Microtus* (Hamilton, 1937; Calhoun, 1945, Pearson, 1959), *Neotoma* (Spencer, 1941), *Sigmodon* (Calhoun, 1945), *Reithrodontomys* (Pearson, 1959). Bartholomew and Cade (1957) suggested that no daily periods of dormancy were evident in *P. longimembris*.

Methods

Trapping incidence was used as the index to demonstrate the time of day when activity was most intense as well as the way in which populations reacted to climatic changes in their environment.

Two trapping designs were used. The first was a single U-shaped transect which contained 200 Young-type live small mammal traps spaced at 9.2 m (30 ft) intervals, and baited with rolled oats. This transect (designated as 5CP) was

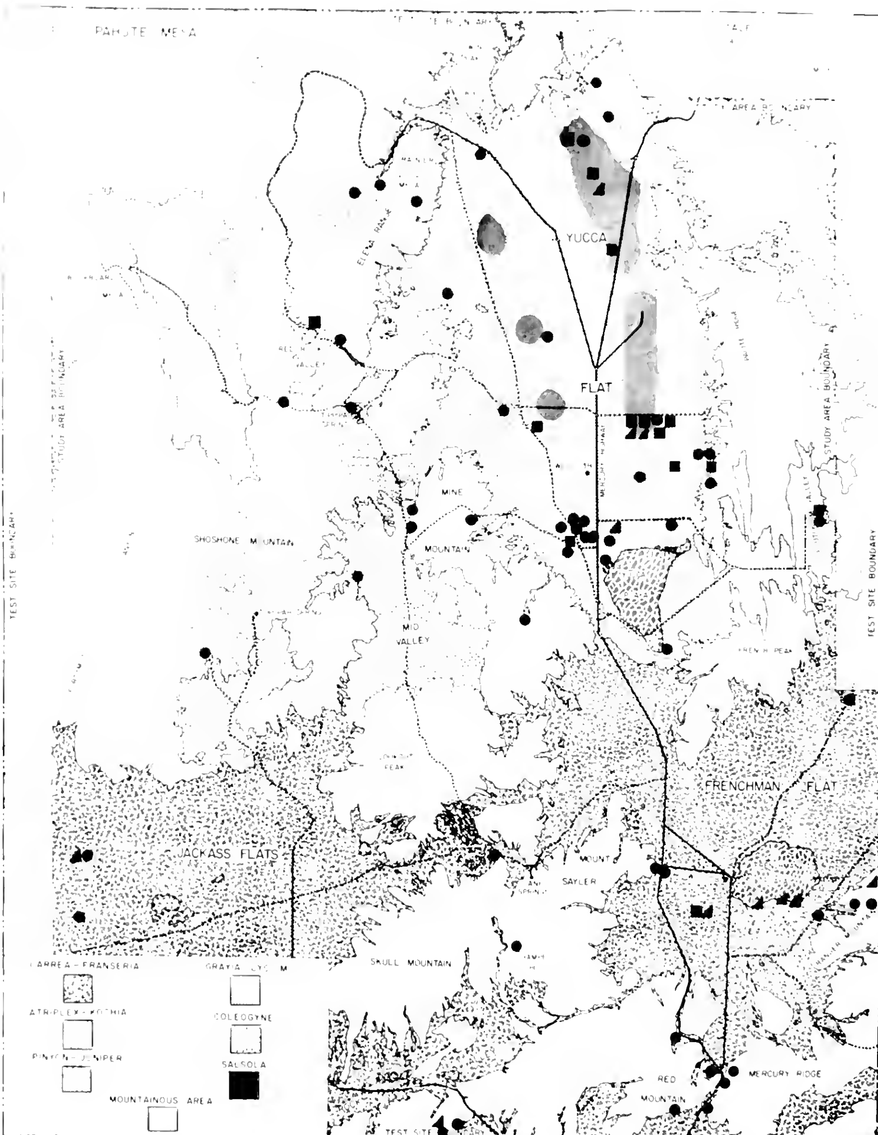


Figure 1. Collection sites of *Dipodomys deserti* (triangles), *Dipodomys ordii* (squares), and *Neotoma lepida* (circles).

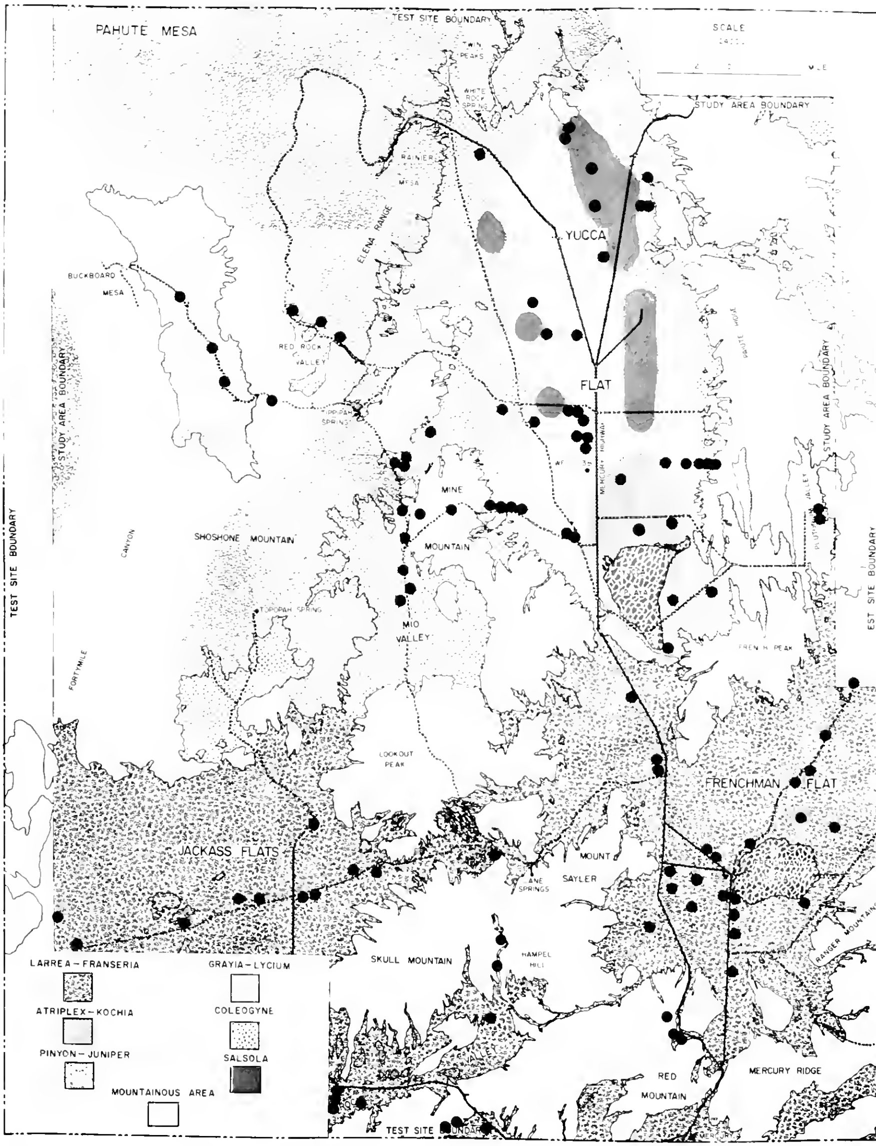


Figure 2. Collection sites of *Perognathus longimembris*.

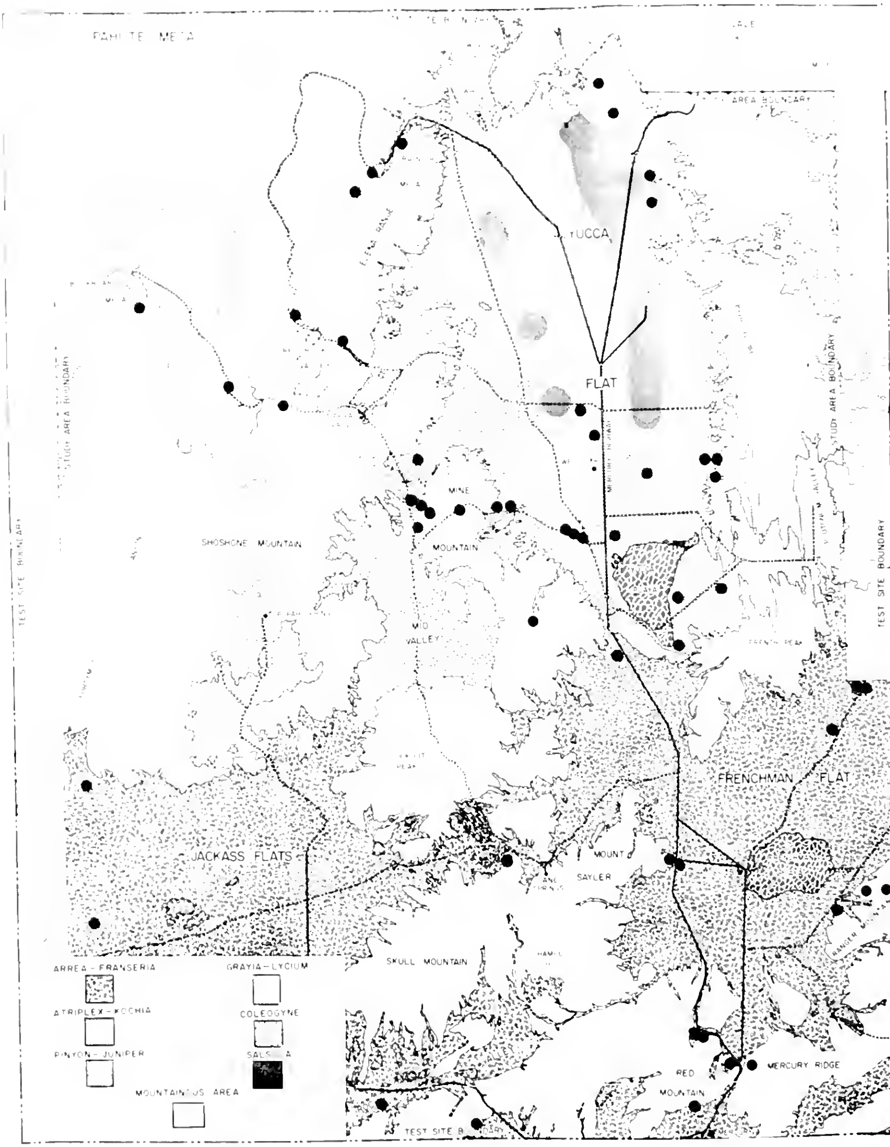


Figure 3. Collection sites of *Peromyscus crinitus*.

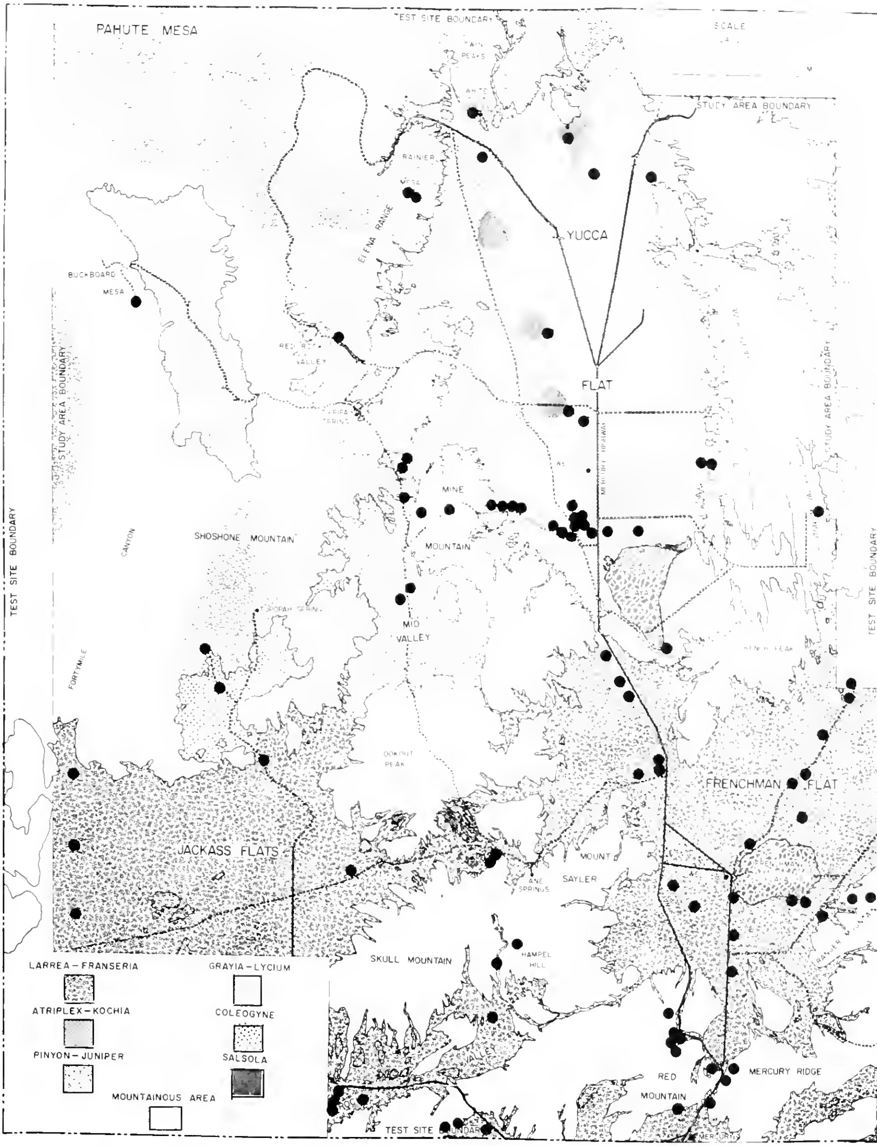


Figure 4. Collection sites of *Perognathus formosus*.

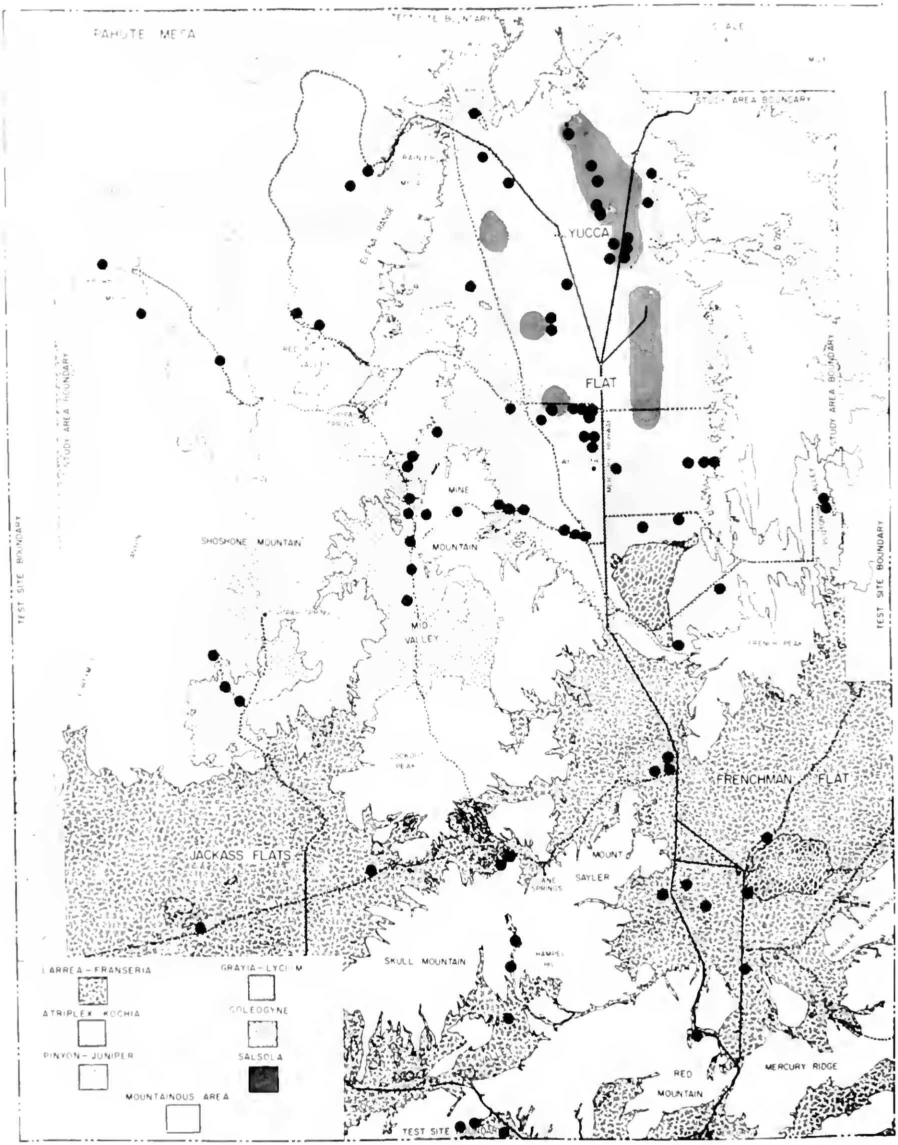


Figure 5. Collection sites of *Onychomys torridus*.

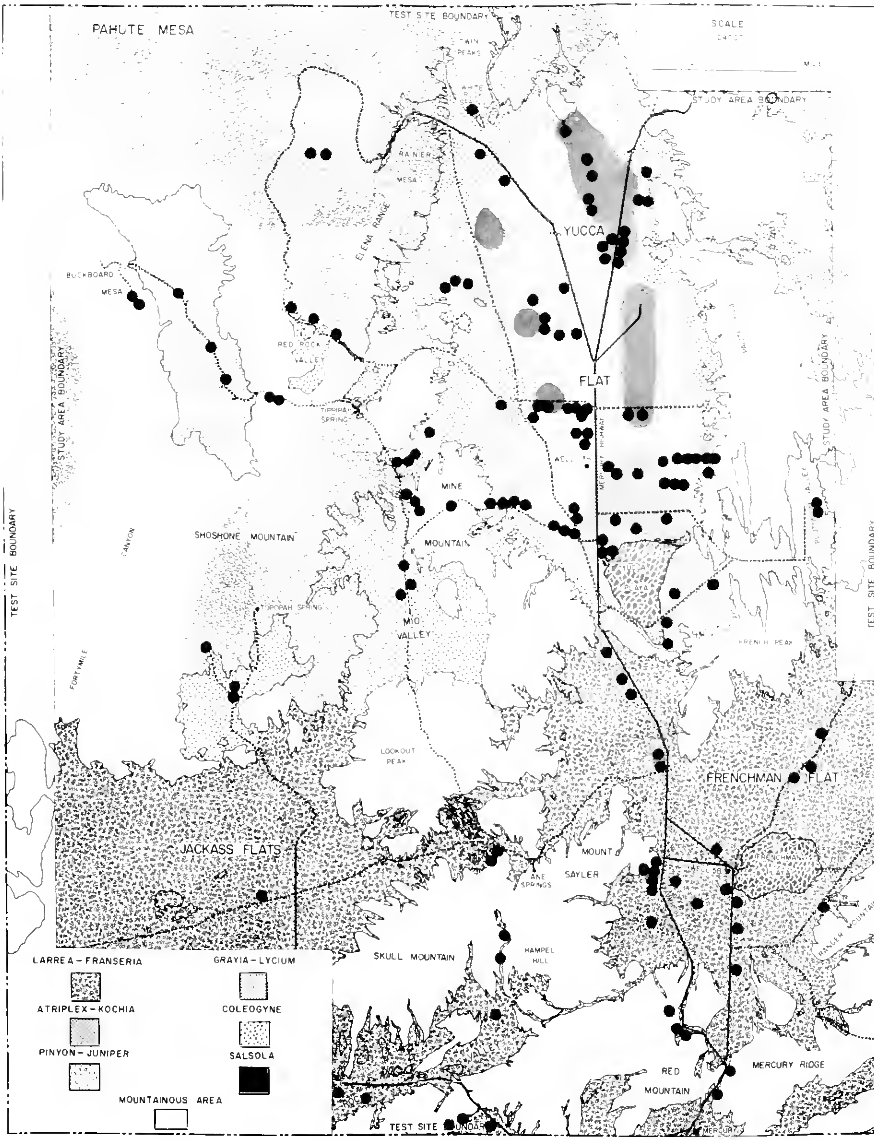


Figure 6. Collection sites of *Dipodomys microps*.

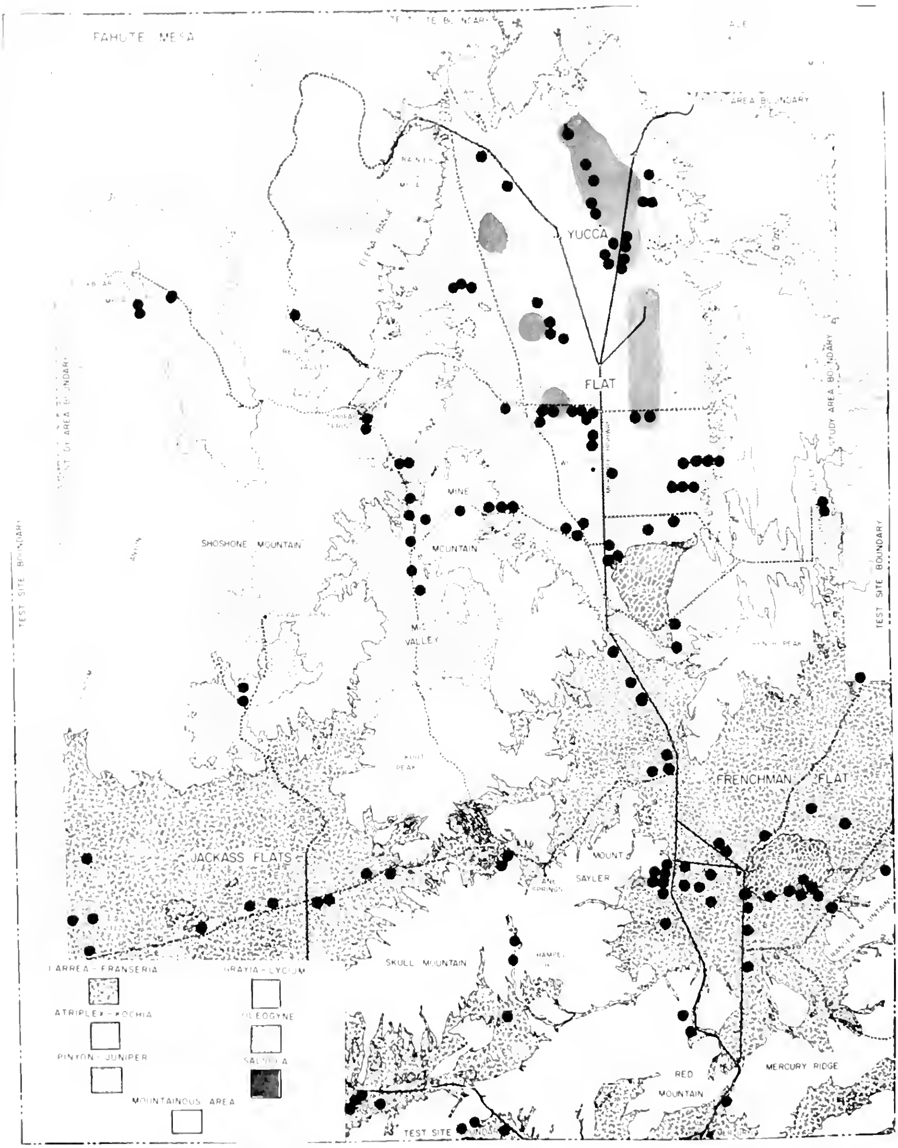


Figure 7. Collection sites of *Dipodomys merriami*.

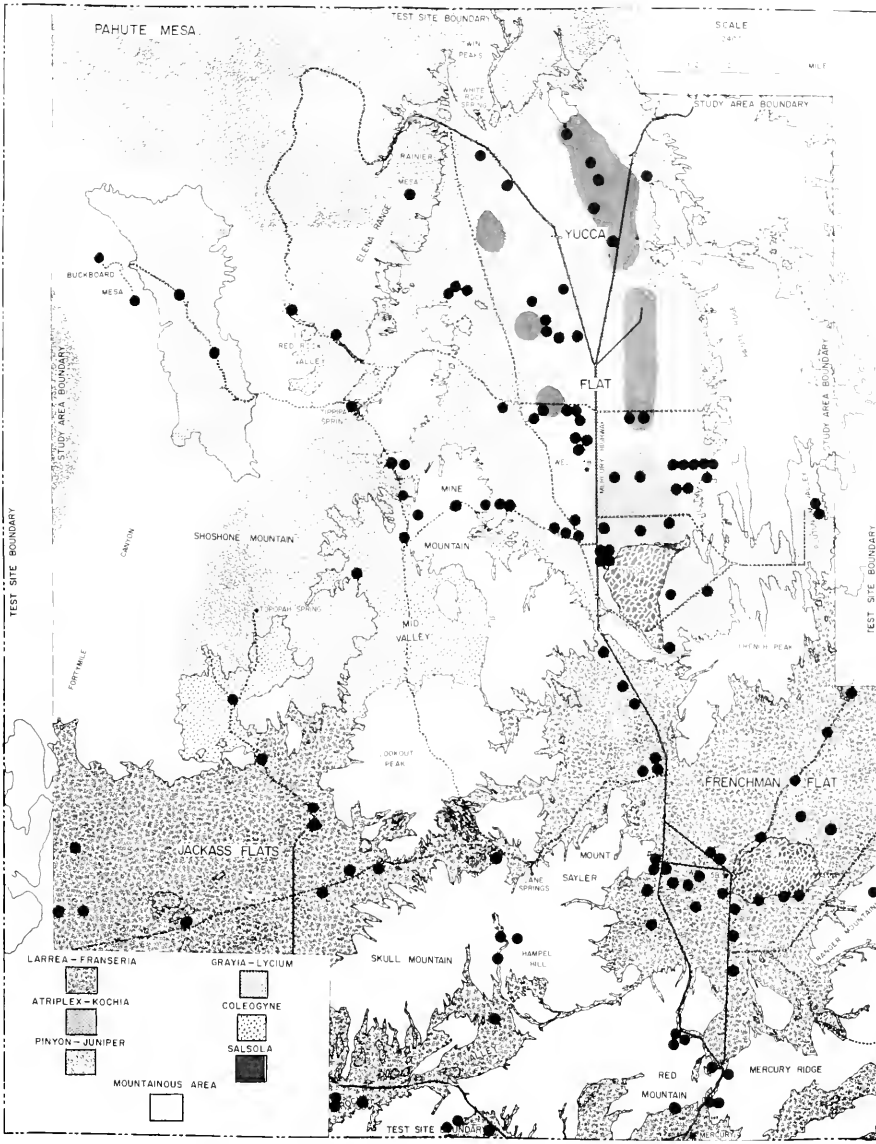


Figure 8. Collection sites of *Ammospermophilus leucurus*.

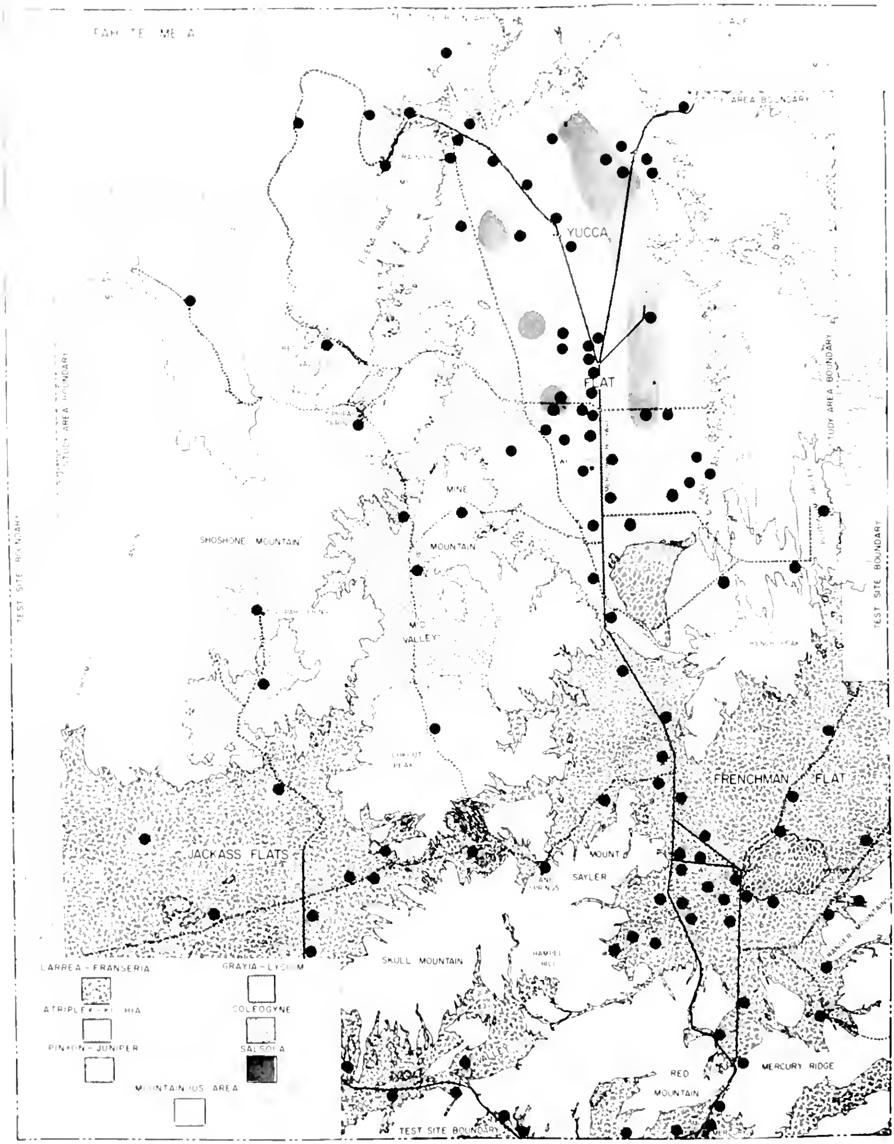


Figure 9. Collection sites and sight records of *Lepus californicus*.

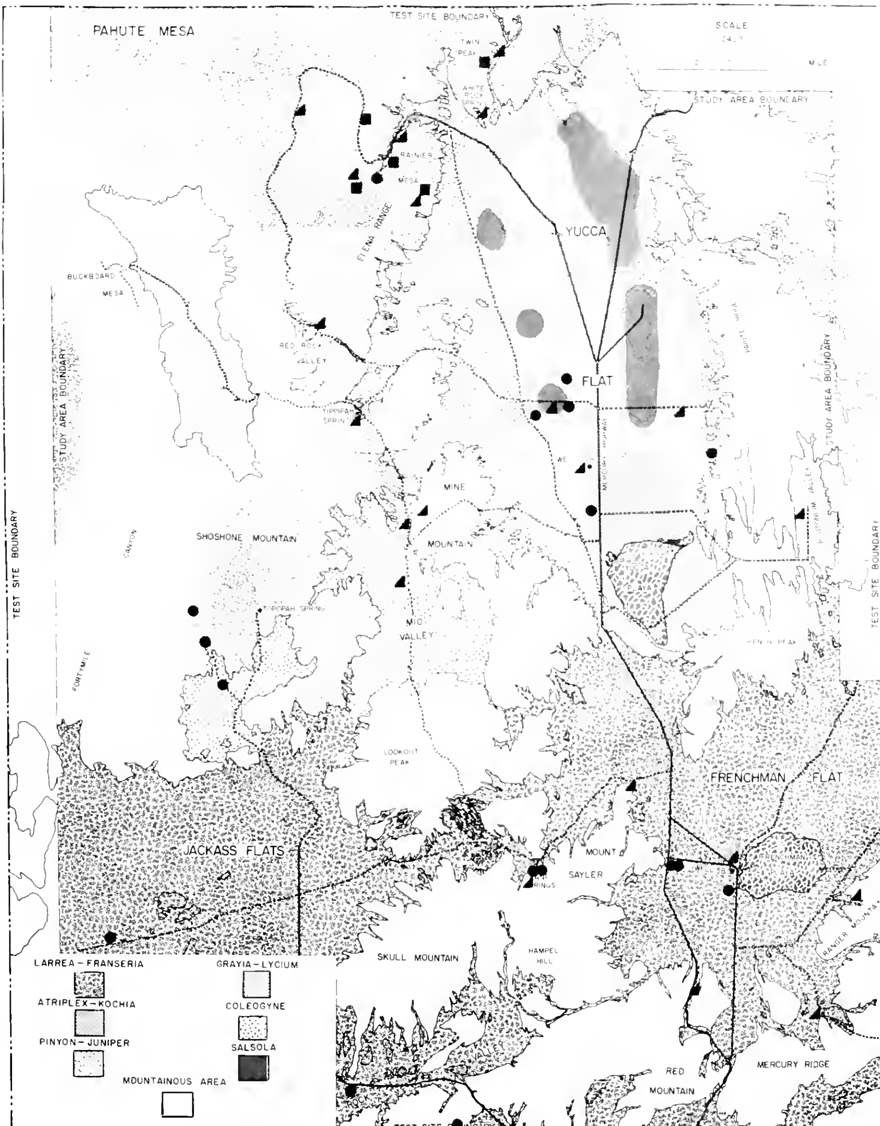


Figure 10. Collection sites of *Thomomys umbrinus* (circles), collection sites and sight records of *Sylvilagus audubonii* (triangles) and *Sylvilagus nuttallii* (squares).

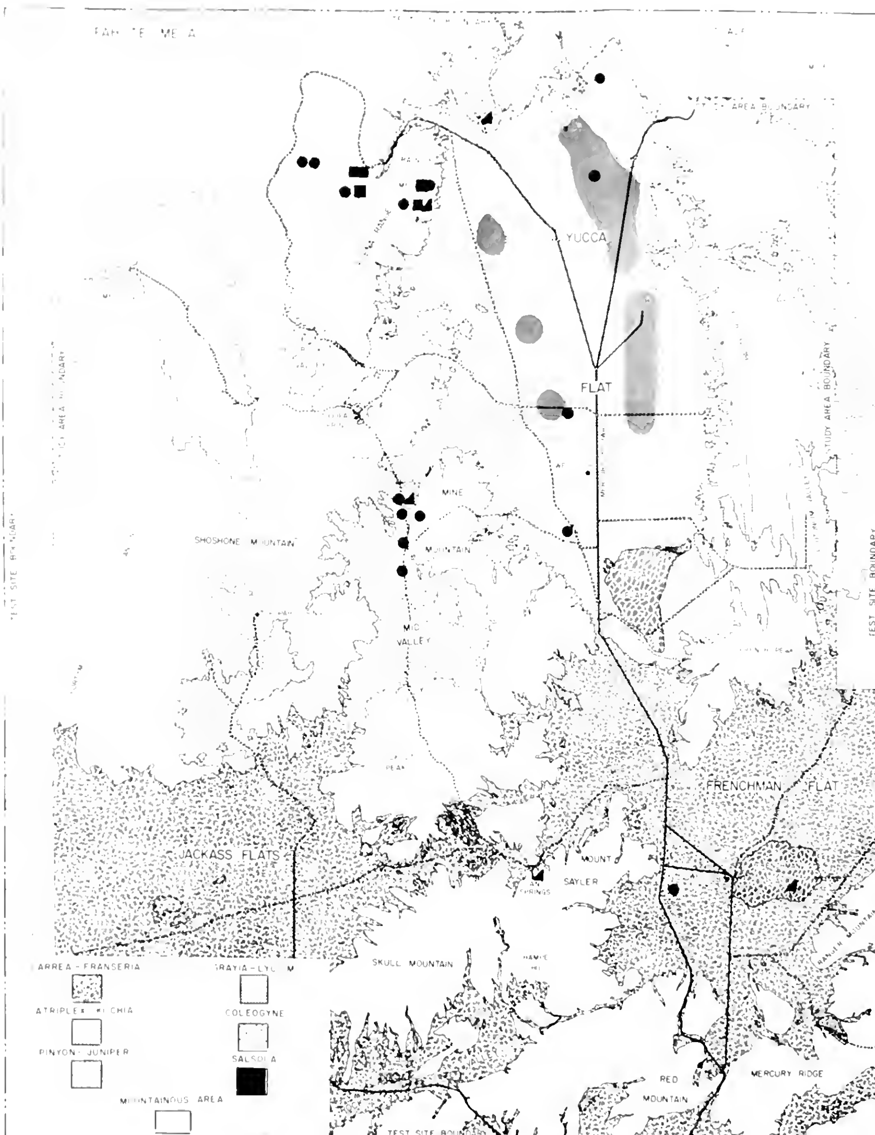


Figure 11. Collection sites of *Eutamias dorsalis* (squares), *Perognathus parvus* (circles), and *Reithrodontomys megalotus* (triangles).

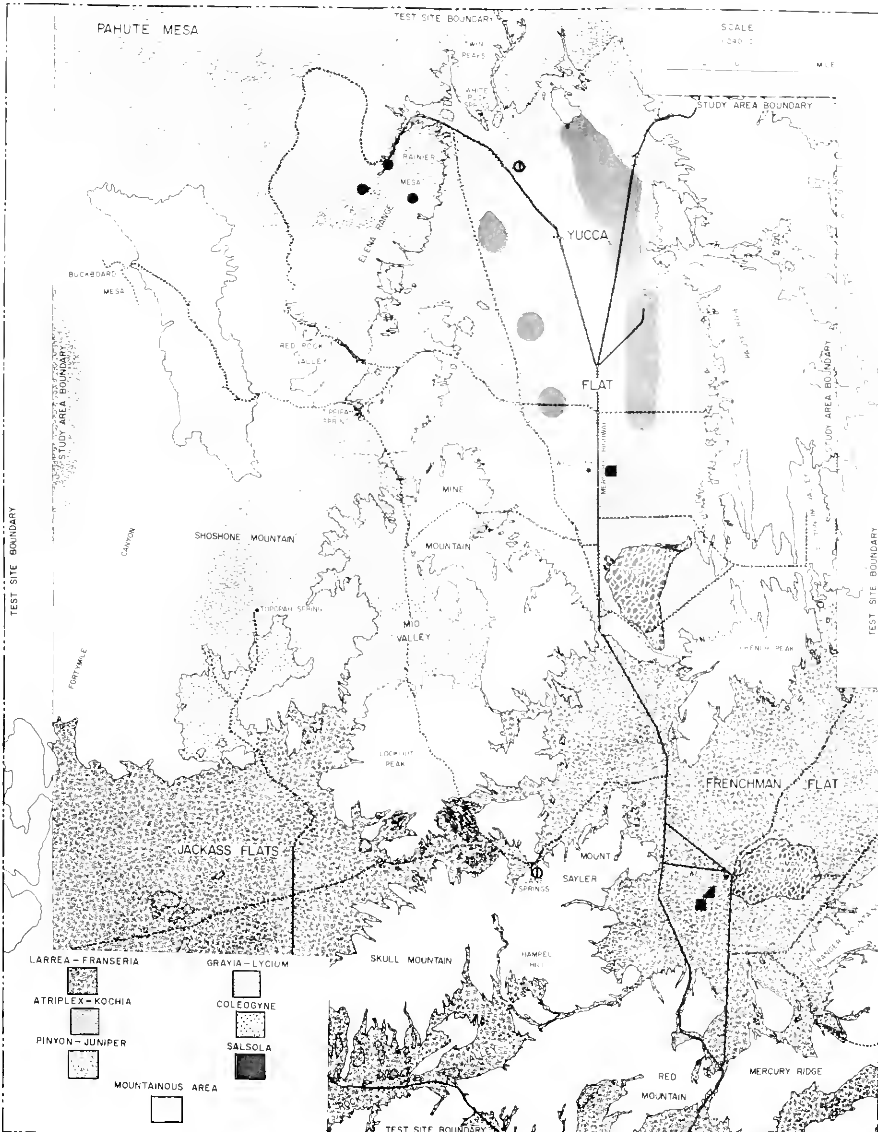


Figure 12. Collection sites of *Spermophilus variegatus* (circles), *Spermophilus townsendii* (squares), *Spermophilus tereticaudus* (triangles) and *Peromyscus eremicus* (slashed circles).

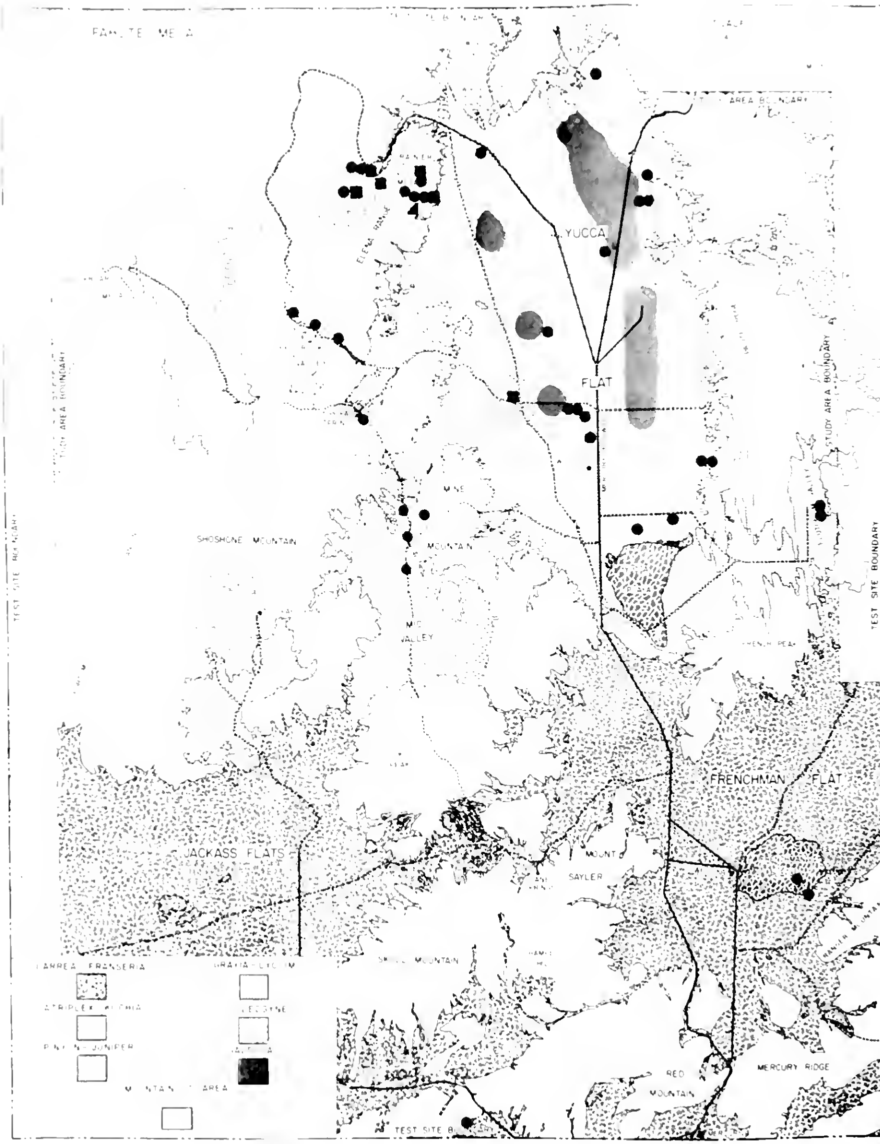


Figure 13. Collection sites of *Peromyscus maniculatus* (circles), *Peromyscus truei* (squares), and *Lagurus curtatus* (triangles).

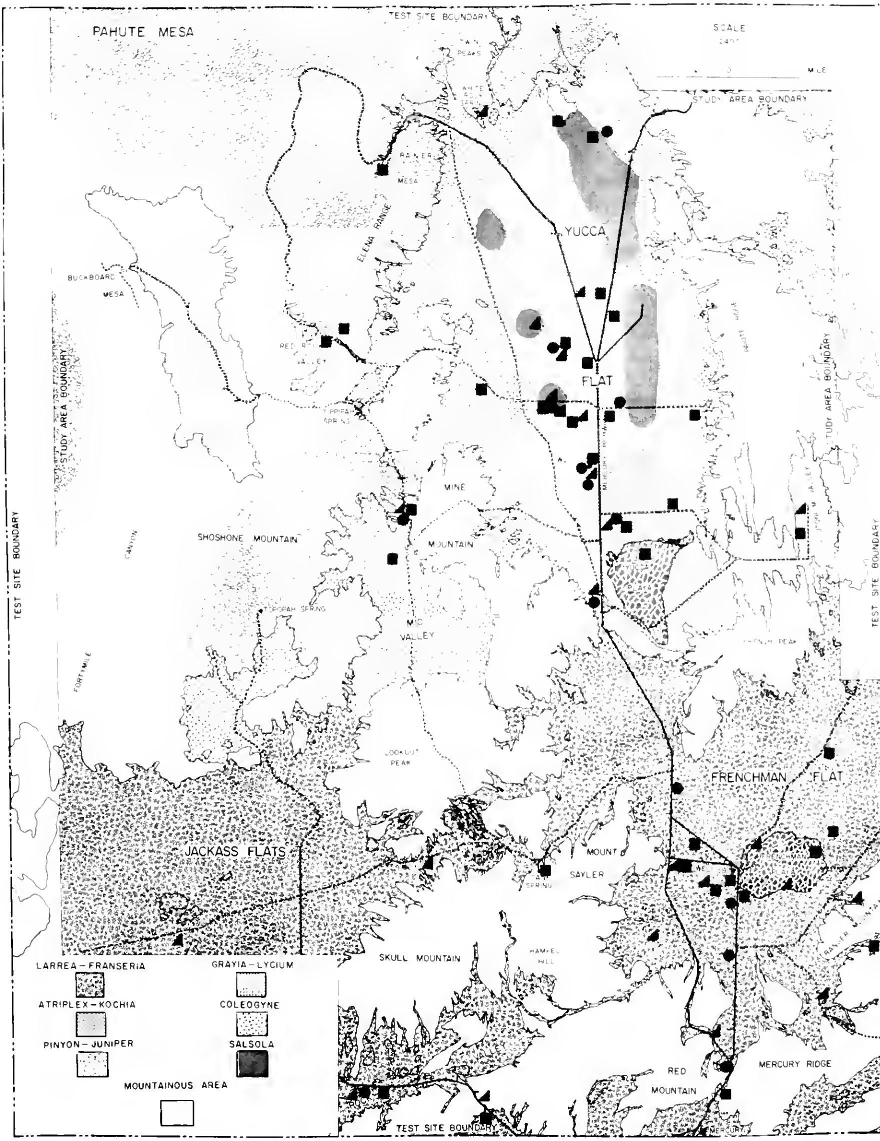


Figure 14. Collection sites and sight records of *Taxidea taxus* (circles), *Vulpes macrotis* (triangles), and *Canis latrans* (squares).

located in a *Lycium pallidum* plant community. Other plant species associated in this community are *Lycium andersonii*, *Grayia spinosa*, *Eurotia lanata*, *Atriplex canescens*, *Atriplex confertifolia*, *Dalea polyadenia*, *Larrea divaricata*, and *Oryzopsis hymenoides*.

The second design (designated as 1F) was a grid consisting of six transects, each with 12 Young-type live small mammal traps. The transects and the traps were 22.9 m (75 ft) apart; thus, the grid covered 31.2 ares (7.81 acres) and contained 72 traps. Study 1F was located in an area in Yucca Flat which had previously been denuded of its original vegetation by nuclear weapons testing between 1952 and 1957. The grid was in a *Salsola kali* plant community. Other plant species common in this area were *Oryzopsis hymenoides*, *Chaenactis stevioides*, and several other less abundant annuals. See Allred, Beck and Jorgensen (1963b) for the precise location of 5CP and 1F.

Traps were checked once each hour for 48 consecutive hours each month from February through August. Before animals from 5CP were released, the date, time of capture, species, sex, stage of development, and ambient temperatures were recorded. The animals from 1F were marked with a combination of ear and toe clips and their identifying marks were recorded along with the data listed above before they were released. In this manner the activity of individuals as well as the population was recorded.

Temperature readings were taken 3 dm (12 in.) below ground surface, upon ground, and 12.19 dm (48 in.) above the ground surface. Temperatures were measured with a Tele-thermometer.[3] Meteorological factors such as cloud cover, wind, and phase of the moon were also noted. Sunrise and sunset were recorded for each plot since the time period differed slightly between them.

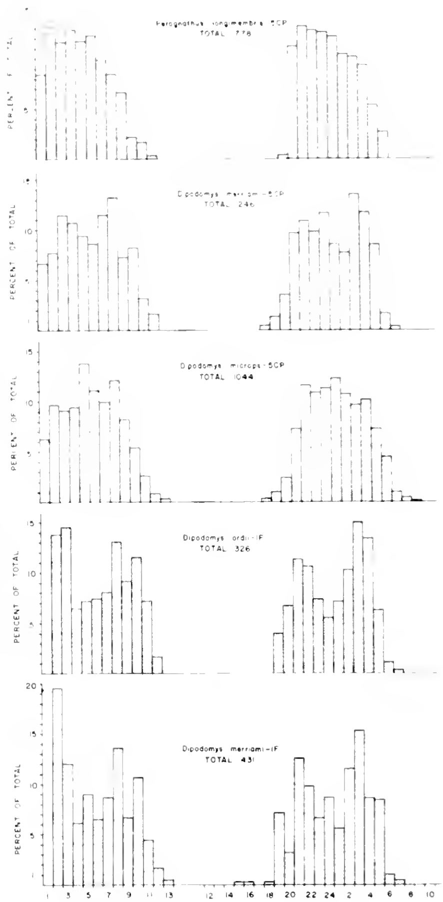


Figure 15. Composite graph depicting the percent of total captures plotted for each hour after sunset, and for the time of day when they were captured.

RESULTS

Diel Cycles

Since hours between sunset and sunrise vary slightly from month to month, any one time of day cannot be interpreted equally each month. To effect an equal starting point, sunset was selected as a common starting point for each night's observations, and the hours of the night enumerated as hours after sunset. This adjustment became necessary when it was evident that the time of sunset was important in the activity of these desert species of small mammals. Figure 15 presents a summary of the diel activity when plotted before (time of capture) and after (hours after sunset) the adjustment for sunset. Because the length of the nights varies during the year, observations at the right ends of the curves do not represent identical conditions of light.

Activity of *D. merriami*, *D. microps*, *D. ordii*, and *P. longimembris* was nocturnal, beginning soon after sunset and frequently persisting for

[3] Tele-thermometer, models 43TC and 43TE, manufactured by Yellow Springs Instrument Company, Inc. Yellow Springs, Ohio.

a short time after sunrise. Activity of *A. leucurus* was entirely diurnal. *Dipodomys ordii* and *D. merriami* had activity peaks near the second hour after sunset and again between the eighth and tenth hours. *Dipodomys microps* also had two peaks, but the first appeared about the fifth hour after sunset rather than the second. *Perognathus longimembris* reached its activity peak on the second hour after sunset, maintained it through the fifth hour, and then decreased.

From Figure 15 it is apparent that the mode of plotting can make considerable difference in the interpretation. This is particularly evident in the 1F study plot. It is our opinion that plotting of these types of data should be adjusted to some common denominator such as sunset, in order that a more realistic concept of their diel activity can be established. This seems more reliable even though the right ends of the curves are not directly comparable.

Hourly Fluctuations

Aside from an obvious temperature decrease at the time activity commenced and a subsequent increase when activity subsided, no correlation was evident between animal activity and temperature fluctuations (Fig. 16-28).

Dipodomys merriami, D. ordii, and *D. microps* - There was no correlation between moonlight and trapping activity. For example, some extreme activity fluctuations were observed in 1F during July (Fig. 28) and the moon was never obstructed by clouds. Similar fluctuations were observed in May (Fig. 26) when the moon was frequently concealed by clouds. These concealments were not correlated with depressions or peaks in animal activity. During the April 21-23 period in 5CP (Fig. 18) when the moon set near midnight there was a distinct increase of activity after the moon went down on April 22, but not on April 23, indicating that there was not a consistent correlation between the lunar events and small mammal activity.

Perognathus longimembris - A sizeable increase was recorded at a time when the moon was concealed by heavy clouds at 0300[4] hours on May 31 (Fig. 19) in 5CP. Short periods of cloudiness had less influence than periods of sustained moonlight interrupted by less frequent cloudiness. Fluctuations did not appear to deviate from the diel cycle on nights when there was no moon. Intermittent rains and cloudiness began at about midnight and lasted for nearly three hours on August 18-19 (Fig. 22) in 5CP. This suppressed activity. A similar reaction was evident on the following night when it rained from 2200 to 2400 hours. The rain ceased for two hours and activity increased, but dropped abruptly with more rain.

Sex Ratios

There were no significant differences[5] between the numbers of males and females, yet the ratios differed from one night to the next. Correlations were not evident between these ratio changes and the meteorological changes.

Dipodomys microps was the only species with a significant[6] seasonal change in its sex ratios. The ratio switched from predominantly males in February and March to predominantly females in May, June, July, and August. The ratio was even during April.

The sexes were simultaneously active each hour for there were no significant differences[7] in the hourly ratios. The right-hand tail of the activity curve (Fig. 15) was excluded from this analysis to avoid possible exaggeration as a result of small numbers being trapped.

Individual Activity

The activity and number of individuals active was examined to determine if their activity influenced population data and daily activity curves. This was determined by using marked *D. merriami* and *D. ordii* trapped in 1F.

The total number of animals trapped is of particular interest because it served as the index of activity. The number of individuals active during any given trapping period was also important. A certain proportion of the animals trapped were not marked, so it was necessary to correct for that by estimating the total number active.

$$n = \Sigma c + \frac{\Sigma c\ (\Sigma a - \Sigma b)}{\Sigma a}$$

a=traps containing animals/hour.
b=traps containing marked animals/hour.
c=the individuals trapped with marks/hour.
n=the individuals active/trapping period (48 hr).

[4]Time is expressed in 24-hours military time: 1200 = noon and 2400 = midnight.

[5]The *t* test was used to test the hypothesis that the difference between population means of males and females was equal to zero ($P < .05$).

[6]Analysis of variance was used to test the hypothesis that the ratio of males and females did not change for each of the months between February and August ($P < .05$).

[7]Analysis of variance was used to test the hypothesis that the ratio of males and females did not change for each hour they were collected during the day ($P < .05$).

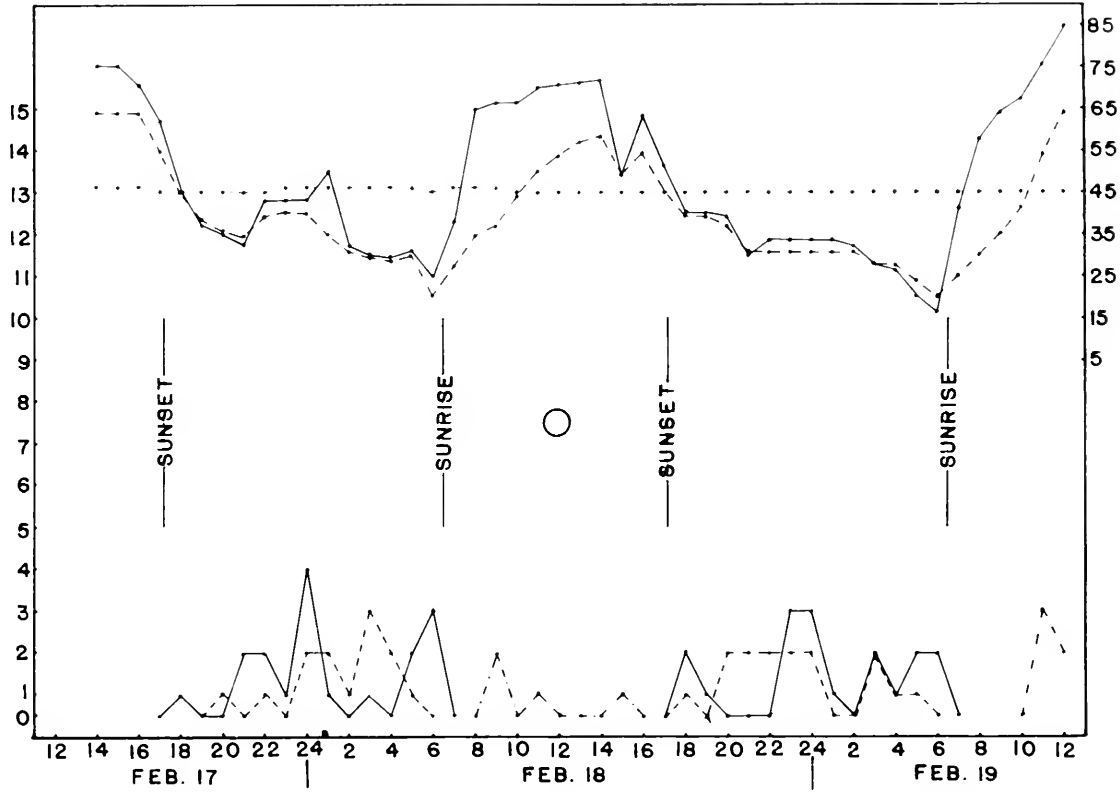


Figure 16. Diel cycles of small mammals in 5CP, February, 1961; no moon (open circle); left ordinate is captures per hour; right ordinate is temperature (degrees F), top continuous line is atmospheric temperature and bottom is *Dipodomys microps*; top dashed line is surface temperature and bottom is *Dipodomys merriami*; top dotted line is subsurface temperature, and bottom dot-dash line is *Ammospermophilus leucurus*.

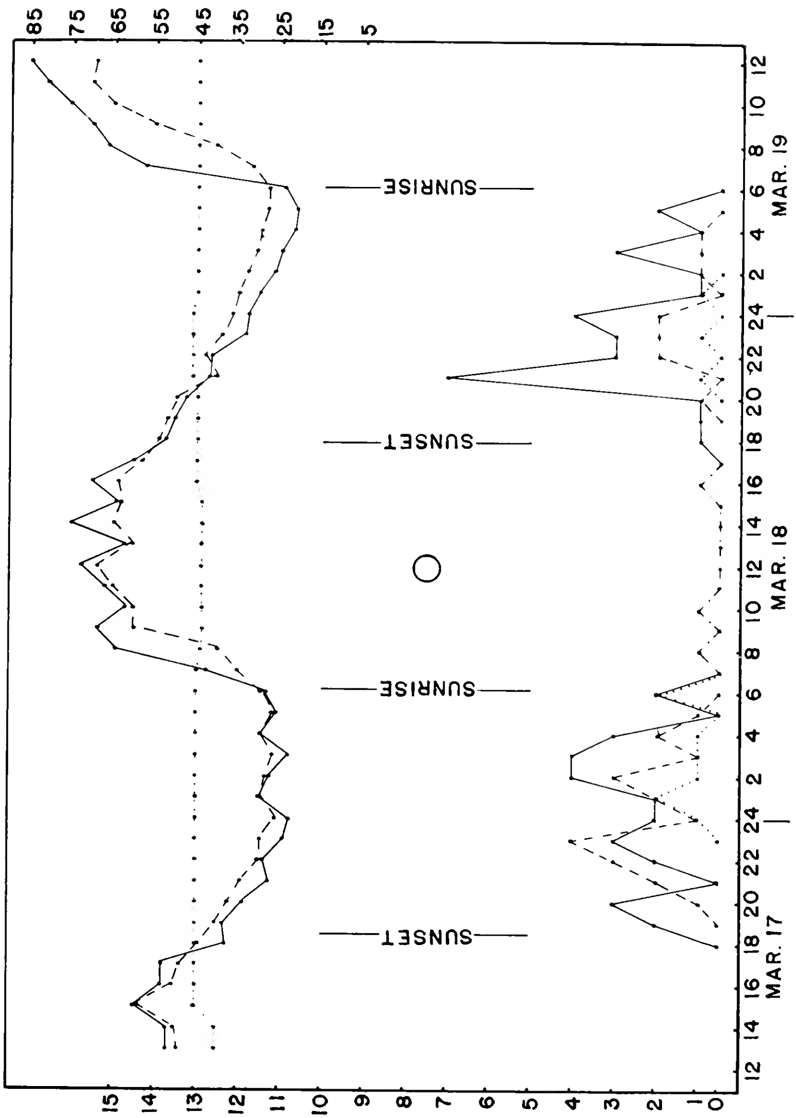


Figure 17. Diel cycles of small mammals in 5CP, March, 1961; no moon (open circle); left ordinate is captures per hour; right ordinate is temperature (degrees F); top continuous line is atmospheric temperature and bottom is *Dipodomys microps*; top dashed line is subsurface temperature and bottom is *Dipodomys merriami*; top dotted line is subsurface temperature and bottom is *Perognathus longimembris*; and bottom dot-dash line is *Ammospermophilus leucurus*.

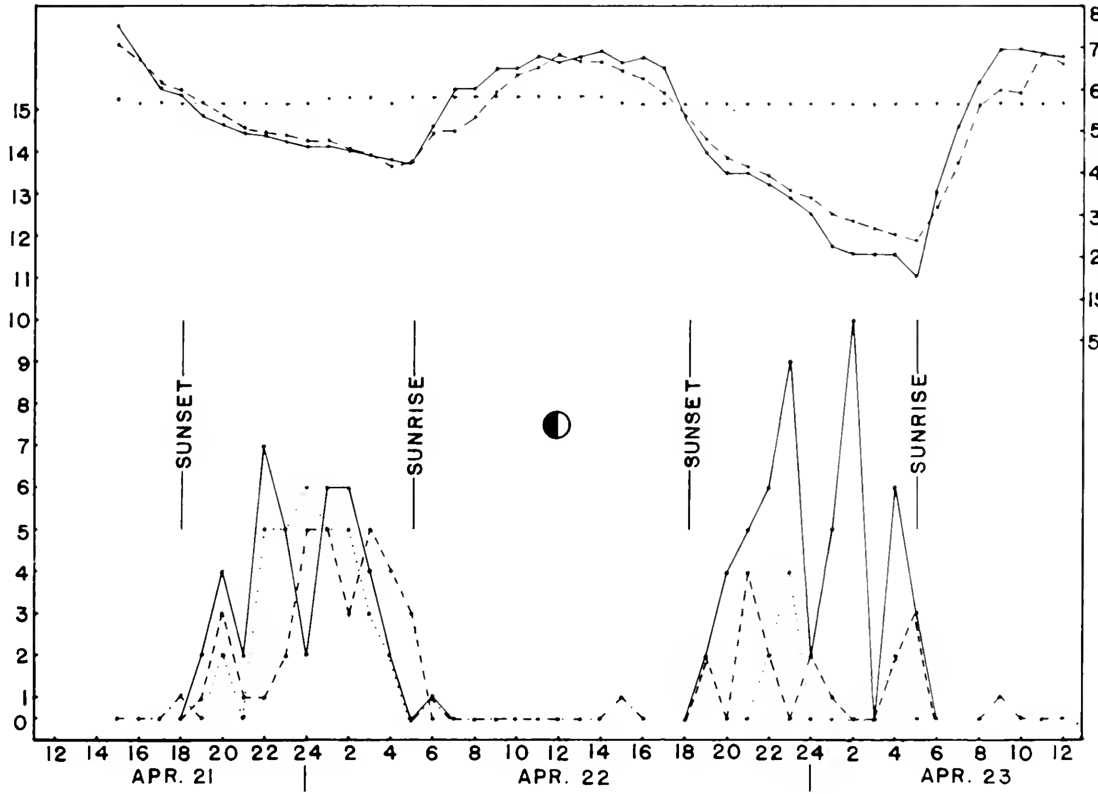


Figure 18. Diel cycles of small mammals in 5CP, April, 1961; partial moon (half closed circle), left ordinate is captures per hour; right ordinate is temperature (degrees F); top continuous line is atmospheric temperature and bottom is *Dipodomys microps*, top dashed line is surface temperature and bottom is *Dipodomys merriami*; top dotted line is subsurface temperature and bottom is *Perognathus longimembris*; and bottom dot-dash line is *Ammospermophilus leucurus*.

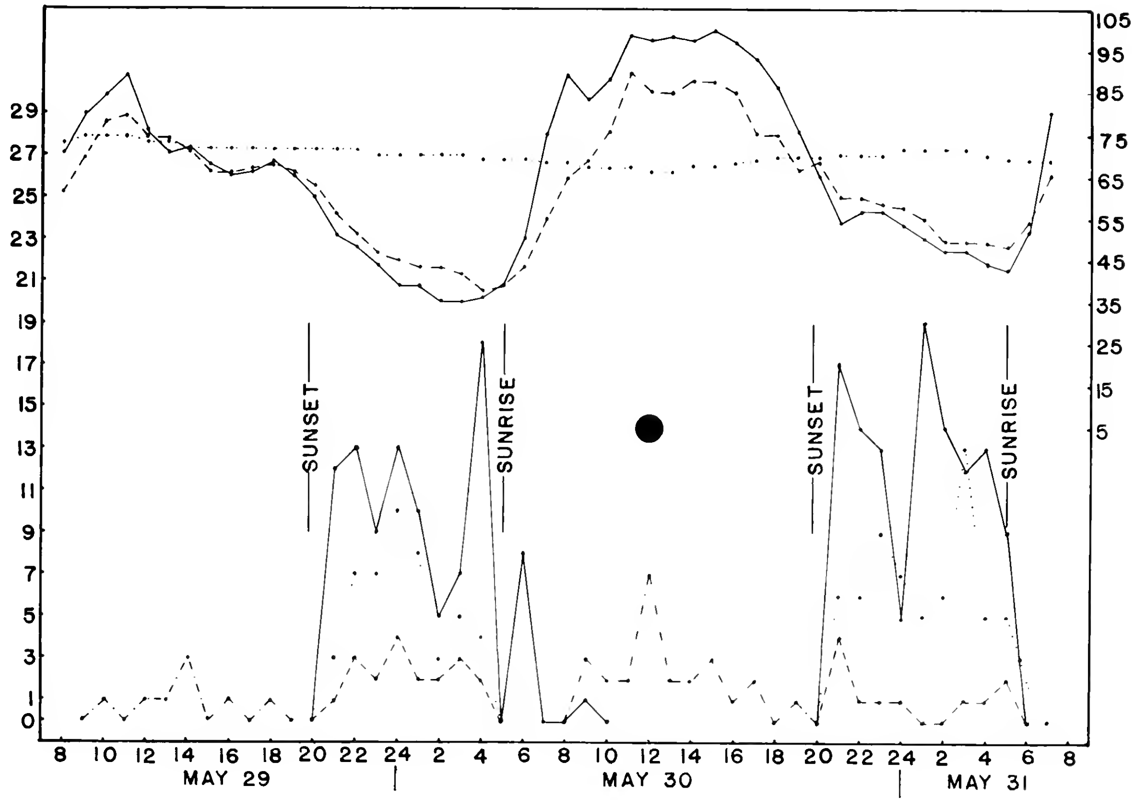


Figure 19. Diel cycles of small mammals in 5CP, May, 1961; full moon (closed circle); left ordinate is captures per hour; right ordinate is temperature (degrees F); top continuous line is atmospheric temperature and bottom is *Dipodomys microps;* top dashed line is surface temperature and bottom is *Dipodomys merriami;* top dotted line is subsurface temperature and bottom is *Perognathus longimembris;* and bottom dot-dash line is *Ammospermophilus leucurus.*

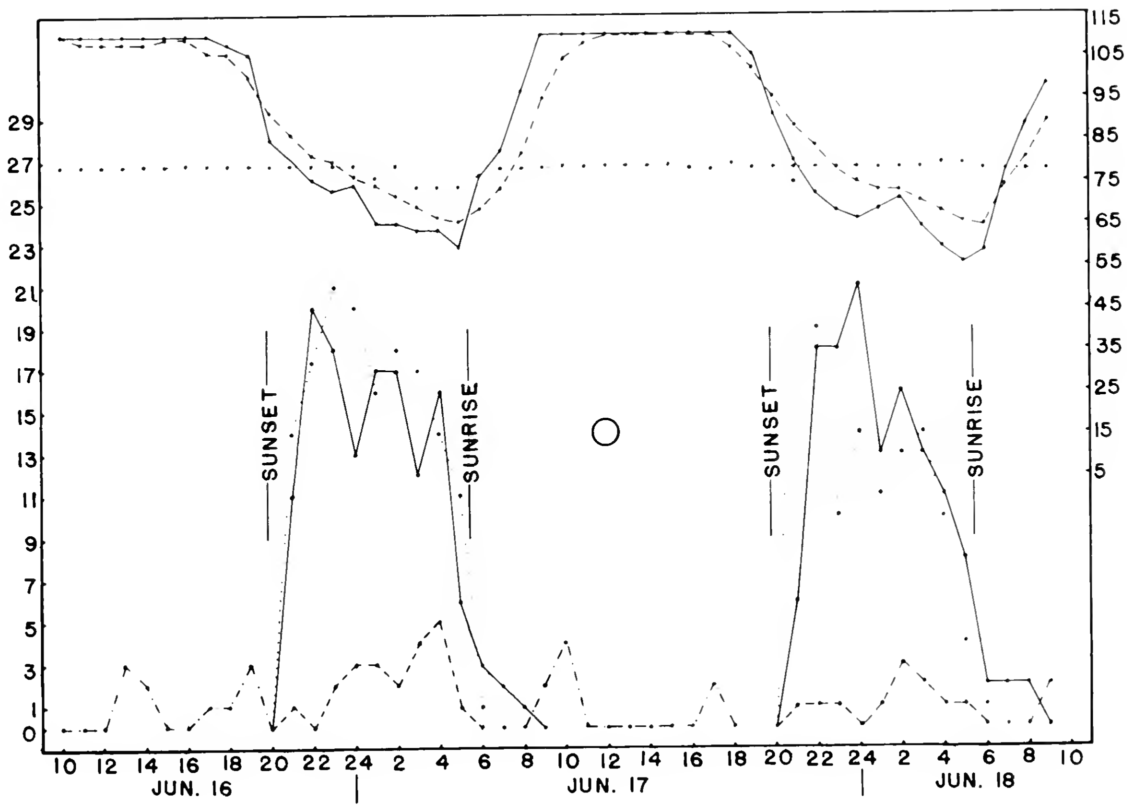


Figure 20. Diel cycles of small mammals in 5CP, June, 1961; no moon (open circle); left ordinate is captures per hour; right ordinate is temperature (degrees F); top continuous line is atmospheric temperature and bottom is *Dipodomys microps;* top dashed line is surface temperature and bottom is *Dipodomys merriami;* top dotted line is subsurface temperature and bottom is *Perognathus longimembris;* bottom dot-dash line is *Ammospermophilus leucurus.*

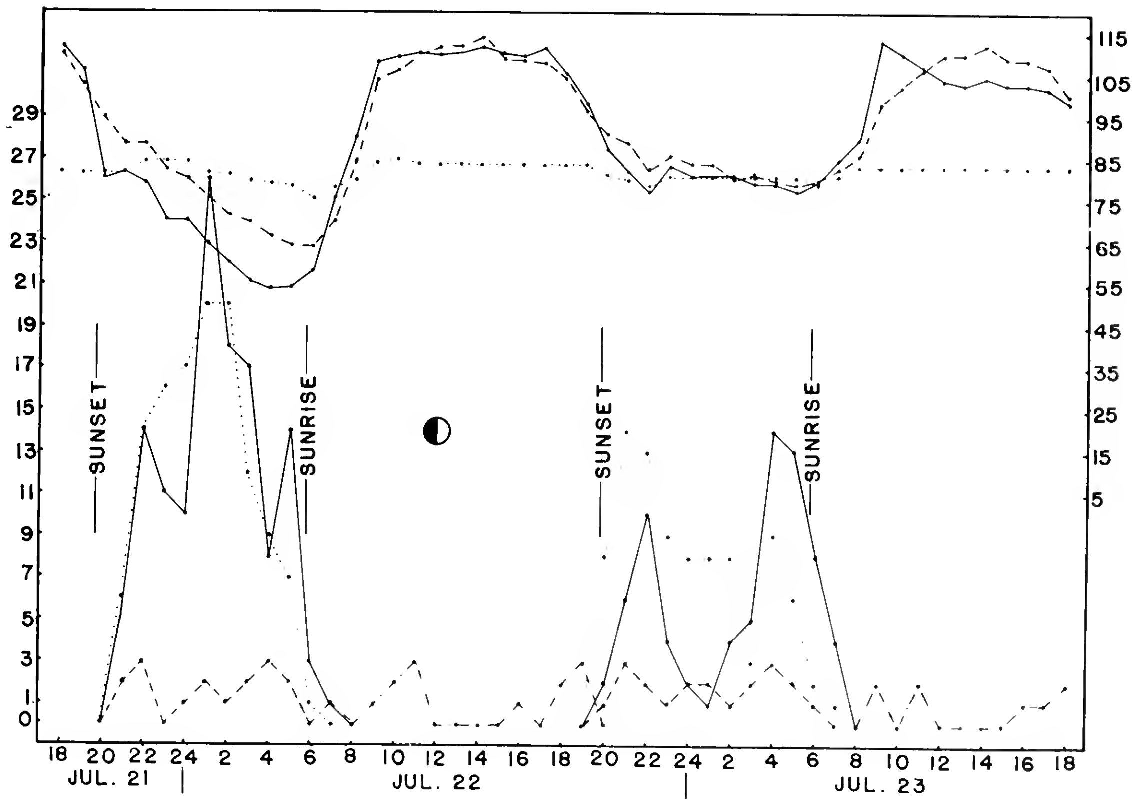


Figure 21. Diel cycles of small mammals in 5CP, July, 1961; partial moon (half-closed circle); left ordinate is captures per hour; right ordinate is temperature (degrees F); top continuous line is atmospheric temperature and bottom is *Dipodomys microps;* top dashed line is surface temperature and bottom is *Dipodomys merriami;* top dotted line is subsurface temperature and bottom is *Perognathus longimembris;* and bottom dot-dash line is *Ammospermophilus leucurus.*

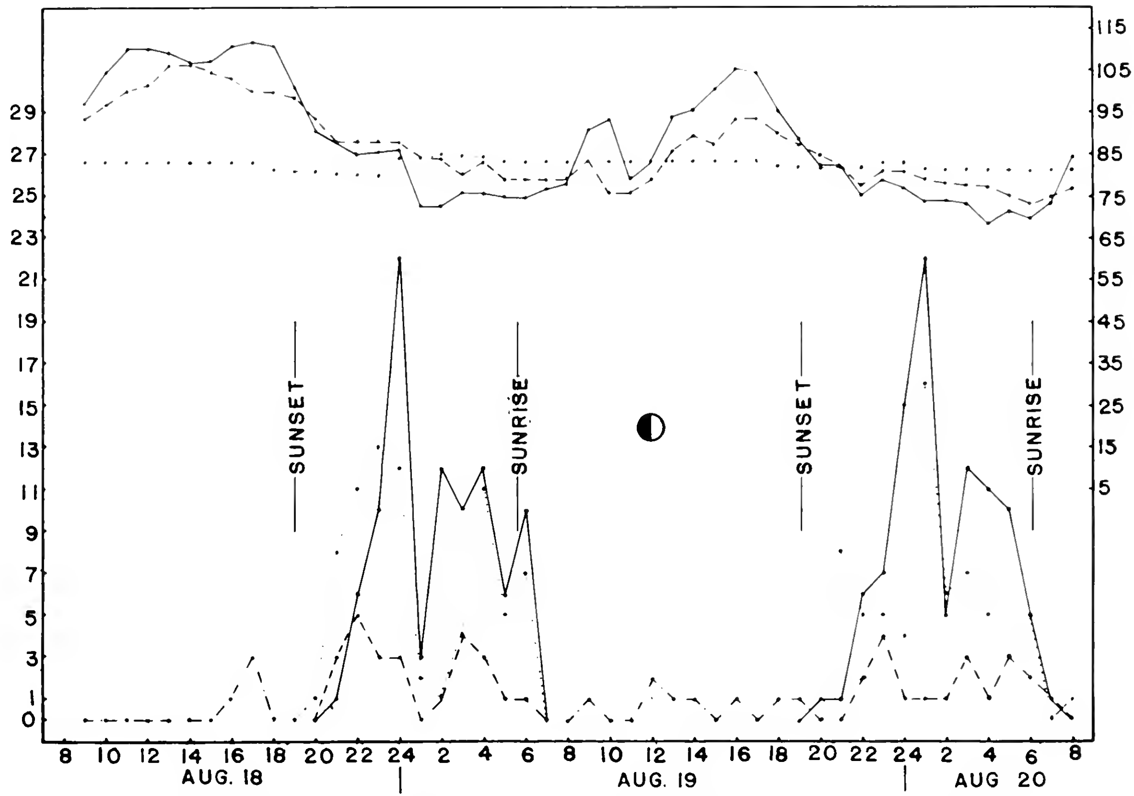


Figure 22. Diel cycles of small mammals in 5CP, August, 1961; partial moon (half-closed circle); left ordinate is captures per hour; right ordinate is temperature (degrees F); top continuous line is atmospheric temperature and bottom is *Dipodomys microps;* top dashed line is surface temperature and bottom is *Dipodomys merriami;* top dotted line is subsurface temperature and bottom is *Perognathus longimembris;* and bottom dot-dash line is *Ammospermophilus leucurus.*

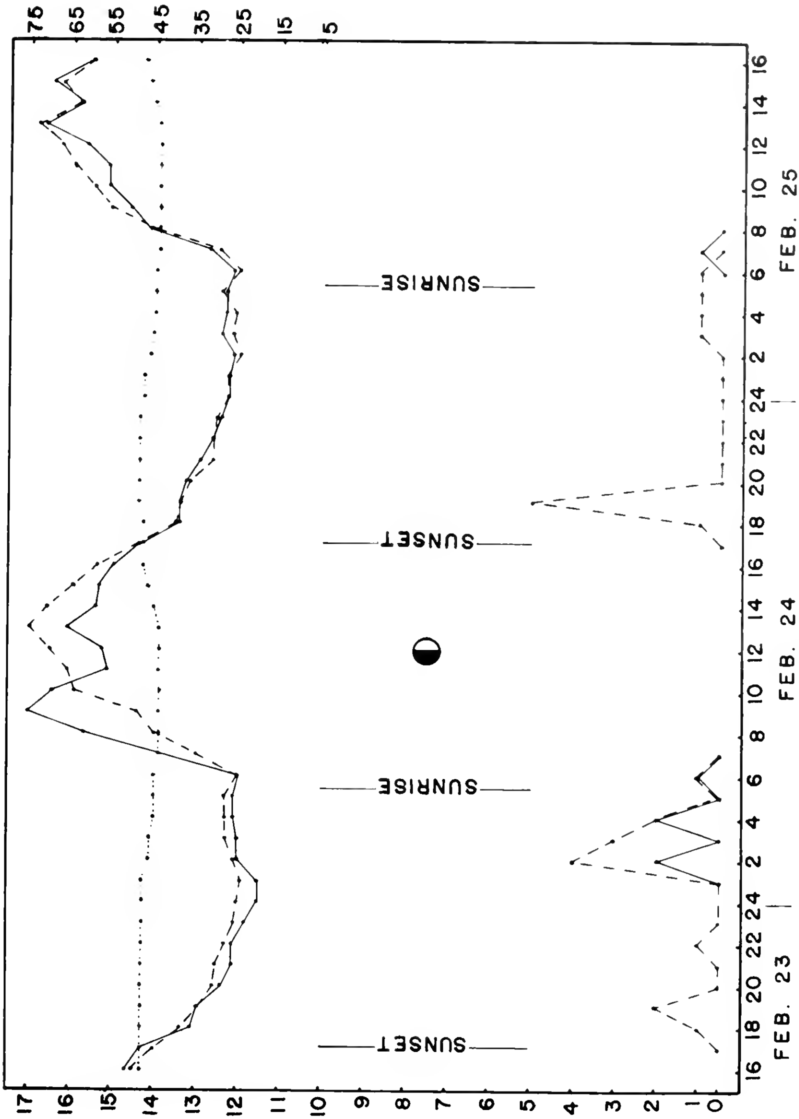


Figure 23. Diel cycles of small mammals in 1F, February, 1961; partial moon (half-closed circle); left ordinate is captures per hour; right ordinate is temperature (degrees F); top continuous line is atmospheric temperature and bottom is *Dipodomys ordii*; top dashed line is surface temperature and bottom is *Dipodomys merriami*; and top dotted line is subsurface temperature.

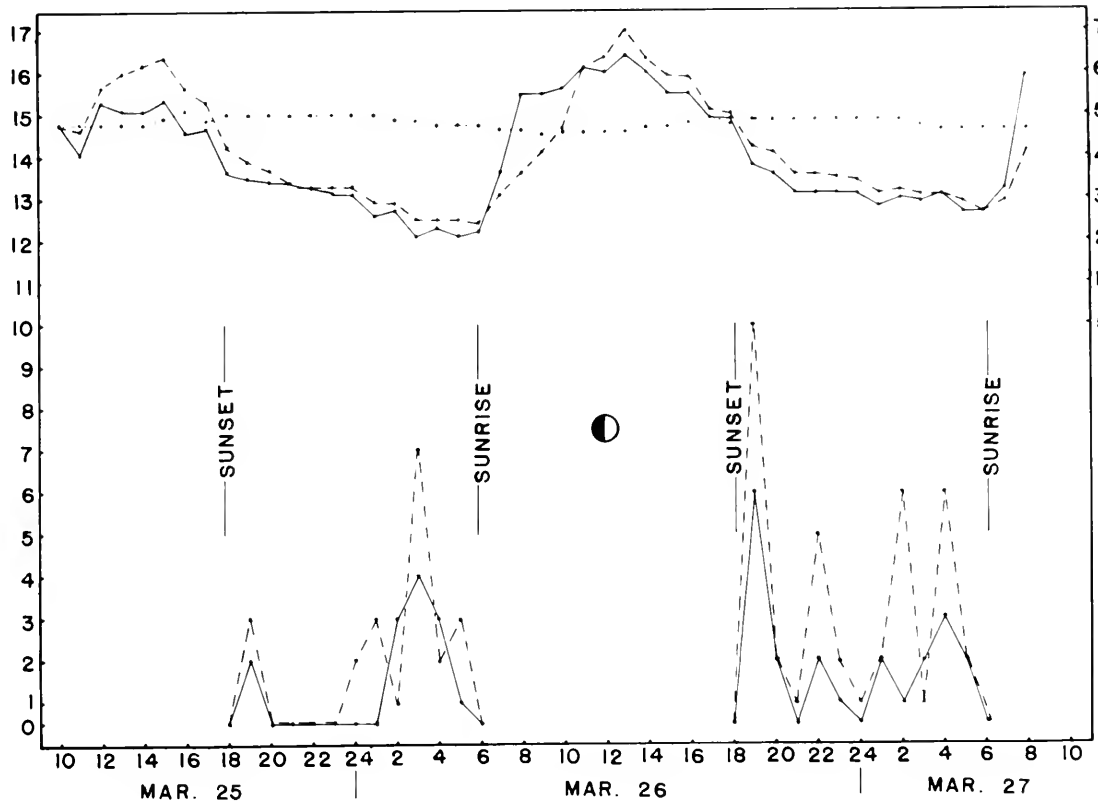


Figure 24. Diel cycles of small mammals in 1F, March, 1961; partial moon (half-closed circle); left ordinate is captures per hour; right ordinate is temperature (degrees F); top continuous line is atmospheric temperature and bottom is *Dipodomys ordii;* top dashed line is surface temperature and bottom is *Dipodomys merriami;* and top dotted line is subsurface temperature.

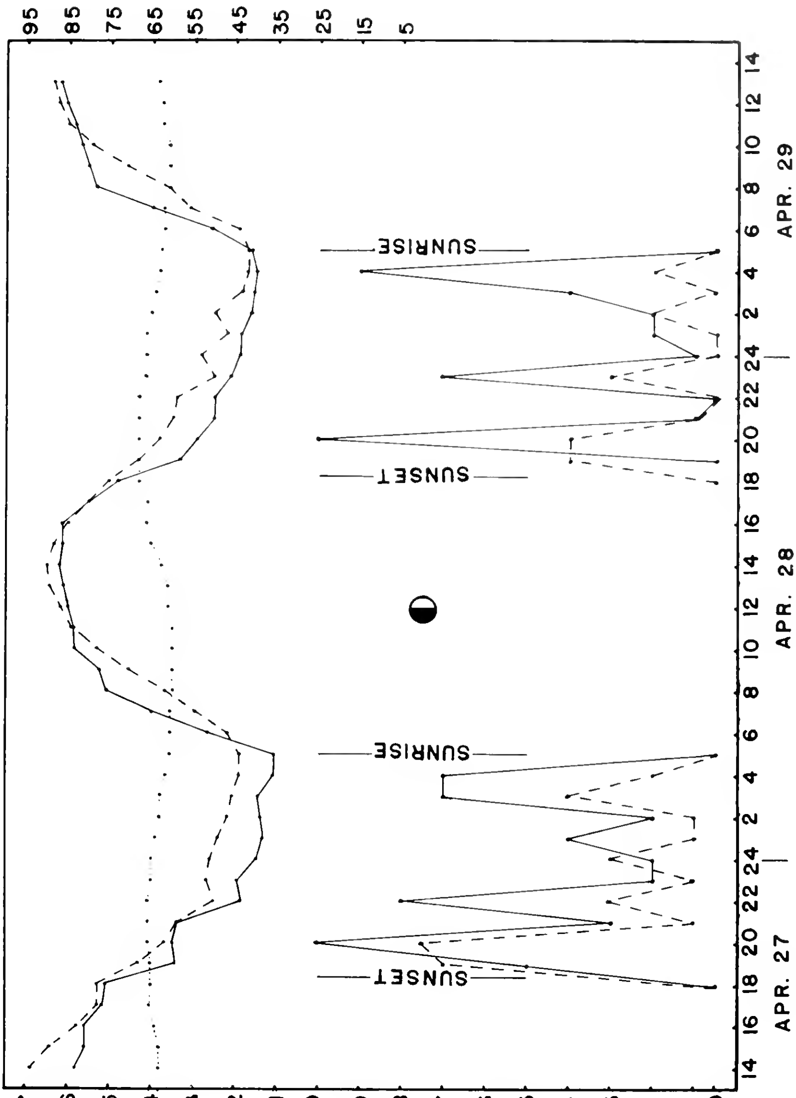


Figure 25. Diel cycles of small mammals in 1F, April, 1961; partial moon (half-closed circle); left ordinate is captures per hour; right ordinate is temperature (degrees F); top continuous line is atmospheric temperature and bottom is *Dipodomys ordii;* top dashed line is surface temperature and bottom is *Dipodomys merriami;* and top dotted line is subsurface temperature.

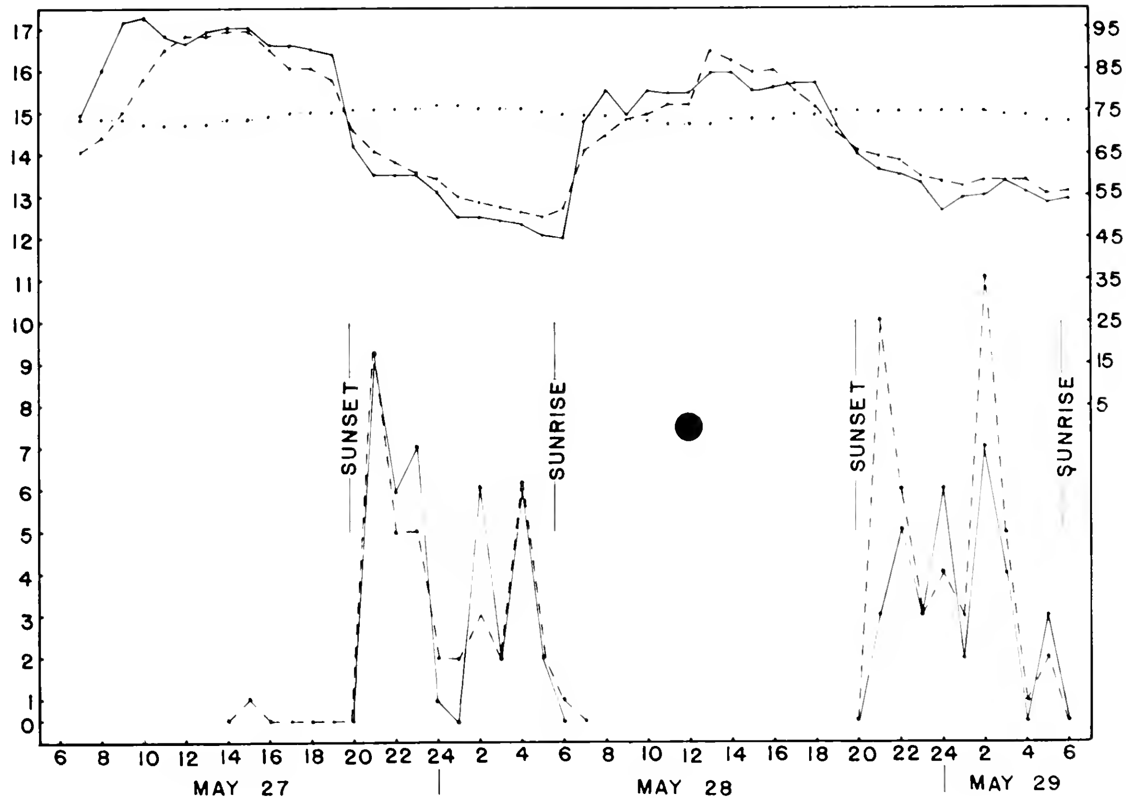


Figure 26. Diel cycles of small mammals in 1F, May 1961; full moon (closed circle); left ordinate is captures per hour, right ordinate is temperature (degrees F); top continuous line is atmospheric temperature and bottom is *Dipodomys ordii;* top dashed line is surface temperature and bottom is *Dipodomys merriami;* and top dotted line is subsurface temperature.

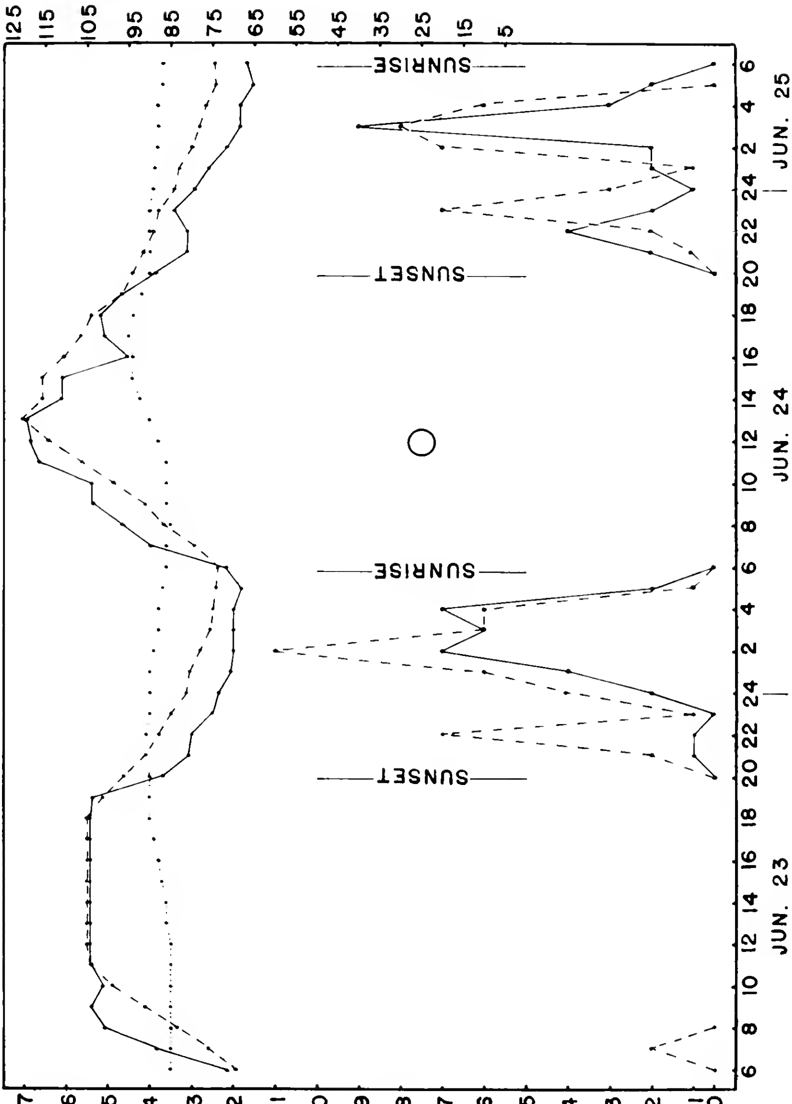


Figure 27. Diel cycles of small mammals in 1F, June, 1961; no moon (open circle); left ordinate is captures per hour; right ordinate is temperature (degrees F); top continuous line is atmospheric temperature and bottom is *Dipodomys ordii*; top dashed line is surface temperature and bottom is *Dipodomys merriami*; and top dotted line is subsurface temperature.

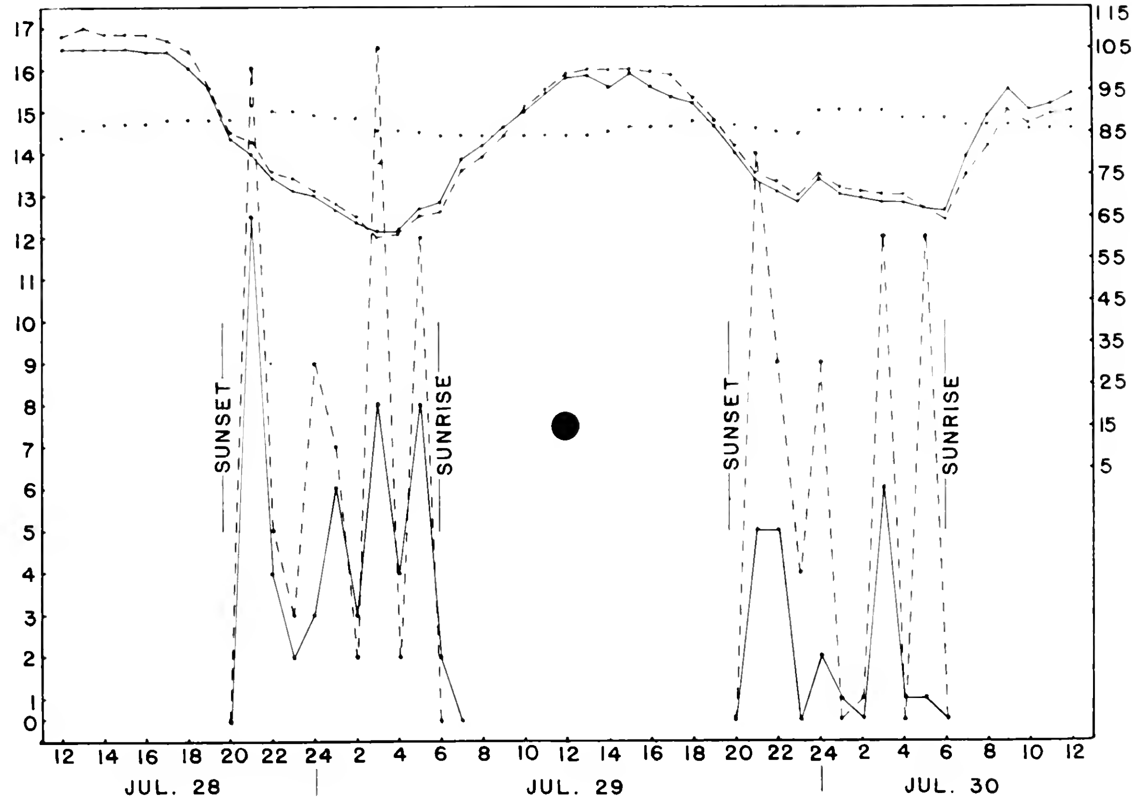


Figure 28. Diel cycles of small mammals in 1F, July, 1961; full moon (closed circle); left ordinate is captures per hour, right ordinate is temperature (degrees F); top continuous line is atmospheric temperature and bottom is *Dipodomys ordii*, top dashed line is surface temperature and bottom is *Dipodomys merriami*; and top dotted line is subsurface temperature.

Using this estimate and assuming that marked and unmarked animals were equally likely to be trapped, the values for n were computed and presented in Table 5. Following the estimation of the number of animals actually involved (n) in determining the extent of activity (Σa), correlation coefficients were computed between them. There was a positive correlation ($P<.05$) with *D. merriami* ($r=.924$) but, no correlation with *D. ordii* ($r=.728$). The values of r were transformed to z with the method illustrated by Snedecor (1946) and the value of t was determined to evaluate density dependency of the two species. Neither *D. merriami* nor *D. ordii* appeared to be density dependent ($P<.05$). The frequency that individuals were active was measured by grouping them into several categories which could then be expressed in percentages (Table 6).

Movement

The distance between traps where an individual was captured was measured to determine how far an animal moved during one night or a single trapping period. This was not intended to measure the actual range of movement, but only the distance between trapping stations traveled by individuals during a single night or trapping period.

Dipodomys merriami - Table 7 summarizes the movement of *D. merriami* and relative numbers of animals participating in each distance category. Movement was primarily less than 45.7 m (150 ft) since 85.8% did not exceed that distance during one night. In one trapping period 80.0% moved less than 45.7 m (150 ft). The maximum distance moved in one night and a single trapping period was 248.5 m (815 ft).

Table 5. Corrected number of *Dipodomys merriami* and *Dipodomys ordii* individuals that were active during each trapping period in 1F; a = traps containing animals/hour, b = traps containing marked animals/hour, c = the individuals trapped with marks/hour, and n = corrected number of individuals which were active/trapping period.

Species	Month	Σa	Σb	Σc	n
Dipodomys merriami					
	Feb	23	23	16	16.00
	Mar	59	43	23	29.23
	Apr	47	45	23	23.97
	May	80	66	21	24.67
	Jun	73	45	18	24.90
	Jul	136	91	39	51.90
Dipodomys ordii					
	Feb	5	5	4	4.00
	Mar	35	23	16	21.48
	Apr	88	69	19	23.10
	May	74	56	16	19.89
	Jun	59	26	6	9.36
	Jul	78	49	21	28.81

Table 6. Summary of individual activity of *Dipodomys merriami* and *Dipodomys ordii* during a trapping period (48 hr).

Period or Activity	*Dipodomys merriami*		*Dipodomys ordii*	
	Total	Percentage	Total	Percentage
Marked	101[a]		61[a]	
Captured				
1 night only/trapping period	63	62.4	28	46.0
Both nights/trapping period	38	37.6	33	54.0
2 times in 1 night/trapping period	50	49.5	46	75.4
3 times in 1 night/trapping period	18	17.8	21	34.4
4 times in 1 night/trapping period	7	6.9	10	9.9
5 times in 1 night/trapping period	2	2.0	4	6.6
2 or more times in PM, not in AM/trapping period	12	11.9	7	11.5
2 or more times in AM, not in PM/trapping period	6	6.0	6	9.8
In PM only	20	19.8	5	8.2
In AM only	18	17.8	11	18.0

[a]All individuals which were marked from February to July are included in this table.

During February 100% moved less than 22.8 m (75 ft), but as the season progressed this percentage decreased until June, when it raised again. In March 64.3% moved 0 - 22.8 m (75 ft), in April 80.0%, in May 16.1%, in June 66.7%, and in July 77.3%. This species moved farthest in May, 16.1% moved between 0 and 22.8 m (75 ft), 23.1% between 22.8 m (75 ft) and 61.0 m (200 ft), 15.1% between 61.0 m (200 ft) and 152.4 m (500 ft), and 23.1% between 152.4 m (500 ft) and 457.3 m (1500 ft). A total of 42.9% moved in excess of 91.5 m (300 ft) during a full moon and 57.1% during a partial moon. No excessive movement was recorded when there was no moon, but this may have been coincidental with months when movement was much reduced for other reasons.

Dipodomys ordii - A summary of movement and relative numbers of animals participating in each distance category is presented in Table 7. The majority (79.6%) moved less than 45.7 m (150 ft) during one night, whereas 75.1% moved this distance in two nights (one trapping period). The maximum distance one animal moved was 388.7 (1275 ft) in one night and 457.3 m (1500 ft) in a single trapping period.

All animals moved less than 22.8 m in February, but as the season progressed this percentage decreased until May when it began to rise again. In March 80.0% moved less than 22.8 m (75 ft), in April 64.3%, in May 18.2%, in June 50.0%, and in July 71.0%. This species moved farthest in May, 18.2% moved between 0 and 22.8 m (75 ft), 27.3% between 22.9 m (75 ft) and 61.0 m (200 ft), 36.4% between 61.1 m (200 ft) and 152.4 m (500 ft), and 27.3% between 152.5 m (500 ft) and 457.3 m (1500 ft). None moved more than 61.0 m (200 ft) in June or July. Of those that moved in excess of 91.5 m (300 ft), 71.4% did so when the moon was full and 28.6% when it was only partially full. No excessive movement occurred when there was no moon, probably because this was coincidental with months when movement was reduced for other reasons.

Spatial Distribution

Distribution of *D. merriami* and *D. ordii* within the grid (1F) was investigated from the point of view of trap utilization and the use of available space. Table 8 presents the percentage of traps that were visited from one to five times in one night and one to six times in a trapping period of two nights. Table 9 presents the percentage of the traps that were visited from one to five consecutive hours. These percentages were derived from an analysis of all 72 traps. It

Table 7. Summary of movement during a single night and a single trapping period (48 hr) for *Dipodomys merriami* and *Dipodomys ordii*, which were trapped two or more times.

Movement in meters	Percentage of animals that moved			
	One night		Two nights	
	merriami	*ordii*	*merriami*	*ordii*
0 - 22.8	65.2	53.6	58.3	42.7
22.9 - 45.7	20.6	26.0	21.7	32.4
45.8 - 68.6	6.5	7.8	3.3	2.8
68.7 - 91.5	1.1	3.1	3.3	8.3
91.6 - 114.3	3.3	1.6	5.0	5.5
114.4 - 137.2	0.0	1.6	1.7	2.8
137.3 - 160.1	0.0	3.1	0.0	0.0
160.2 - 182.9	1.1	0.0	1.7	0.0
183.0 - 274.4	2.2	1.6	5.0	0.0
274.5 - 457.3		1.6		5.5
Total	16	14	12	10

Table 8. Percentage of traps that were visited by *Dipodomys merriami* and *Dipodomys ordii* 1-6 times during one night, and 1-6 times in a single trapping period (48 hr).

Month	One night					Two nights					
	1	2	3	4	5	1	2	3	4	5	6
Feb	26	03				40	07	04			
Mar	33	13	04			72	33	18	04	03	01
Apr	53	28	19	10	03	65	42	29	24	17	11
May	54	29	15	06	06	83	51	33	22	08	07
Jun	49	28	17	13	07	68	47	35	24	15	11
Jul	78	53	35	13	04	83	72	56	46	29	26

Table 9. Percentage of traps that were visited by *Dipodomys merriami* and *Dipodomys ordii* on 1 - 5 consecutive hours of one night.

Month	Hours of Consecutive Trapping				
	1	2	3	4	5
Feb	40				
Mar	72	08			
Apr	65	14	01	01	
May	83	25	06	01	
Jun	68	43	08	01	04
Jul	83	39	04	01	01

is apparent from Table 8 that the percentage of traps visited twice during a single night was rather low (3 - 53). In two nights the percentage increased considerably (7 - 72). The percentage of the traps that were visited twice on consecutive hours was low (8 - 43). A rapid percentage decrease was noted as the number of visits was increased.

It seemed best to demonstrate spatial distribution by using the month of July, in which the largest number of captures was recorded. All other months were similar. The captures plotted on a grid revealed no consistent pattern of distribution (Fig. 29). The distribution changed from one hour to the next. There were areas which seemed to have more activity than others, but these same areas frequently had less activity on the following night. Even at times when activity was highest large areas had no captures during a given hour, but made several captures

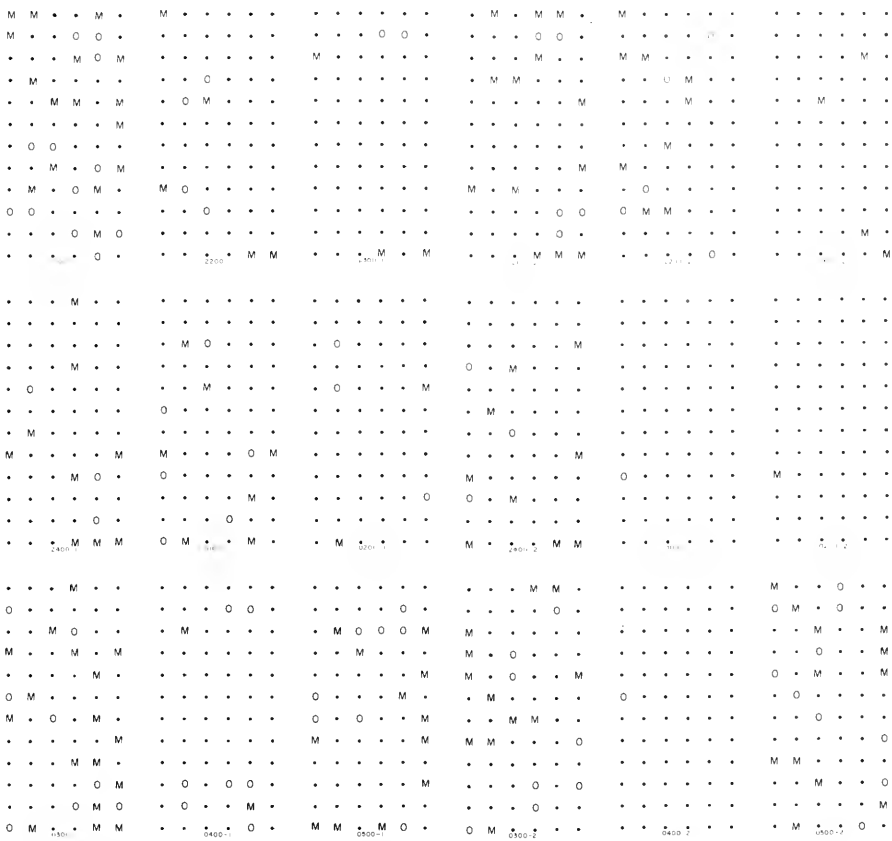


Figure 29. Distribution of captures in 1F during a single trapping period (48 hours) in July, 1961; dots are traps that were empty; 0's are *Dipodomys ordii;* and M's are *Dipodomys merriami.*

during the next hour. Distribution concentrations did not repeat themselves between consecutive nights.

Discussion of Daily Activity

Diel cycles have been studied for several species of small mammals in North America: Bartholomew and Cade (1957), Behney (1936), Calhoun (1945), Chabreck (1962), Foster (1961), Hansen (1957), Johnson (1926), Orr (1959), Pearson (1959), Reynolds (1960), Spencer (1941), and others. These studies were frequently conducted under controlled conditions using small numbers of animals and some records were made of the activity of individual animals only. Data from these reports are valuable in interpreting field data and serve well in understanding the reaction of the population to its environment. Calhoun (1952) stated that as the density of rats increases there is an increase in complexity and frequency of behavior adjustments. If this is so, an increase in activity could effect similar results on behavior adjustments as would an increase in population density. Increased activity would also enhance the possible physical contact of individuals, resulting in greater competitive stresses. These stresses could, in turn, alter phenomena such as longevity and home range. With the apparent influence that activity has on trapping results, it must be considered when interpreting certain population parameters.

Competition among Species

Staggering periods of activity often allows two or more species to occupy the same habitat-niche. This seemed to be the situation at 5CP where *A. leucurus* occupied the area during the day that *D. merriami*, *D. microps*, and *P. longimembris* occupied during the night (Fig. 16-28). Although not nearly as evident *D. merriami* and *D. ordii* also staggered their daily cycles with those of *D. microps* (Fig. 15). The largest peak in activity of *D. microps* was on the fifth hour when *D. merriami* and *D. ordii* were less active. All three species had bi-modal curves, with the second peak between the eighth and tenth hours. They may all have competed with one another for space at this time. *Perognathus longimembris* reached its peak at the same time as *D. merriami* and *D. ordii*. This peak was maintained until after the first peak of *D. microps* before decreasing until sunrise. Although *P. longimembris* may have competed with the kangaroo rats throughout the night, this competition was probably reduced when the rats' second peak was reached.

Competition was not considered in terms of time only, animals also competed for space and food, of which a baited trap was one source. There were large areas in 1F that were without trapped animals from one hour to the next. It appeared that competition was compromised among individuals by staggering space utilization during the night. Although this staggering was not complete, it did at least afford partial relief from competition. Whether or not the animals were forced to compete for a trap is important in trapping analyses. Many attempts have been made to prevent this competition. In most of these cases, the assumption is that all animals in an area competed within the area of their overlapping home ranges. The percentage of traps that were visited on consecutive hours was shown to be rather low, along with the percentage of individuals which were trapped more than twice during any particular night (Tables 8-9). With this and the extremely low percentage of traps that were visited on consecutive hours, the implication is that under the conditions of this grid, competition for traps was not a limiting factor, particularly since animals travel such long distances during a single night.

The problem of mammal distribution over a grid and its importance in population studies has been discussed by Jorgensen (1963). Table 8 demonstrates that the percentage of traps visited just once in a single night was relatively low (26.4 - 77.8). The percentages decreased rapidly as the number of visits was increased. In most cases it approached a 50% decrease from one visit to the next. It was therefore possible that an animal could find a trap at any given hour.

The interesting thing is that 51.5% and 24.6% of *D. merriami* and *D. ordii*, respectively, were trapped only once a night. Reynolds (1960) pointed out that *D. merriami* makes many trips from its burrow each night. From the results of our study it appeared as though most made very few trips during the night since unvisited traps were always available and the percentage of traps that were visited on consecutive hours was so low. This is emphasized even more if the low percentage of individuals that were trapped more than twice during a single night is considered. It is possible that trapping disturbances retarded immediate activity, but this was questioned because a few were repeatedly trapped on consecutive hours. Those individuals that were repeatedly trapped usually visited the same trap over and over again.

Table 6 illustrates that *D. merriami* was more likely than *D. ordii* to be trapped on one

night only during any one trapping period, since it was trapped on one night only 62.4% of the time as opposed to 46.0% for *D. ordii*. Also, *D. ordii* was more apt to be trapped two or more times during any single night. One reason for this might have been their greater movement (Table 7). Farther movements would provide increased trap contact if their home ranges were used in relative intensities from a central locus as suggested by Hayne (1949b) and Calhoun and Casby (1958).

Competition is at least one factor in daily activity which must be considered in terms of daily cycles and their fluctuations. The diel cycles of the population seem to be the result of the number of individuals active at some time of night rather than the extent of their activity. Some of the fluctuations observed between hours on any given night might simply have been due to the number of animals active at that time, rather than to the supposed environmental stresses. There were differences in activity as pointed out in Tables 5 and 6, however, and these differences if not understood could alter the interpretation. With competition reduced, the increase in complexity and frequency of behavior adjustments discussed by Calhoun (1952) which could effect a population increase would also be reduced.

Activity of Different Species

The bi-modal type of curve (Fig. 15) agrees with that described for *D. merriami* by Reynolds (1960), who used the number of trips from a provided nest box as an index of activity. An examination of Reynolds' curve reveals that the number of trips from the nest box was greatest during the AM hours, resulting in the highest point in his curve. In our study the highest point in the curve was during the PM hours. Also, Table 6 shows that *D. merriami* individuals were trapped less frequently two or more times during the AM when not trapped in the PM. Since about the same number of individuals were trapped in the AM and PM, it appeared that activity was most intense during the PM hours rather than the AM hours as described by Reynolds. More individual *D. ordii* were active in the AM than PM, but no more were trapped two or more times. They were probably more active in the PM also, for those that were active were trapped more frequently.

Table 5 illustrates the possibility that the activity of *D. ordii* varies from one month to the next, being most intense from April to July. Thus, fewer animals could effect the illusion of a larger population during these months if only the total (Σa) were considered. During the winter months the same number of animals could be present and appear as a much smaller population because of their decreased activity. The decrease of *D. merriami* (Σa) in the winter months may have been caused by population reduction and/or activity reduction.

A decrease in the number of *D. ordii* individuals active (n) in June is low even though the total number of traps containing animals (Σa) is reduced only slightly. This reduction in Σa was the result of a lack of female activity. Thus, males were apparently either stimulated to increased activity or more traps were simply left available to them. Since males and females were found active simultaneously, it was concluded that the male activity was increased. Although fewer *D. ordii* were active in June, they moved rather far and a large percentage of them moved in excess of 91.5 m (300 ft). This increase in movement may explain the apparent activity increase in Table 5.

It is necessary to have a fair estimate of the number of individuals active before their impression on daily activity cycles can be determined. Although it was not possible to determine the numbers active each hour, which would be necessary to evaluate their effects on fluctuations within the daily activity curve, increased activity of only a few animals did impart an increase in the number captured in a single trapping period. The same reason could certainly be applied to the hourly results, so that activity rather than numbers of individuals would result in the fluctuations. This statement seems adverse to one preceding, " . . . fluctuations . . . on any given night might simply have been due to the number of animals . . . ," but species differ in their habits. *Dipodomys ordii* appeared to have a changing activity intensity, whereas *D. merriami* did not. In the former, activity may have accounted for increased trapping results, while in the latter it may have been an increase in numbers active.

Activity of Different Sexes

Differences in the sex ratios were frequently large and usually unpredictable. In spite of these differences, of the species studied only *D. microps* showed a significant seasonal change in estimated numbers. In this case the change was from predominantly males in the prevernal period to predominantly females in the aestival and serotinal periods. Duke (1944) reported that *D. microps* and *D. ordii* breed from January to March and again from September to October in Utah. The period of predominant male activity for *D. microps* at the test site coincided with the early breeding period defined by Duke. The

period of predominant female activity of *D. microps* coincided rather well with the nonbreeding period illustrated by Duke (1944) and McCulloch and Inglis (1961). The irregularity of activity differences between male and female *D. ordii* made any pattern difficult to detect, and it could not be conveniently correlated with that demonstrated by Duke (1944) or McCulloch and Inglis (1961).

The sex ratios of *P. longimembris* switched from entirely males in March to little difference from April to August. This period (April-August) agrees with the results of Duke (1957), who stated that reproduction in Utah *Perognathus* was from April to July. The results of our studies indicate that the sex ratio for this species was even after the females had emerged from winter hibernation. No females were captured in February, and it is assumed that the large proportion of males was due to their early emergence from winter hibernation. Hall (1946) assumed this species to hibernate and later Bartholomew and Cade (1957) successfully demonstrated both hibernation and aestivation. Since no correlation was evident between environmental stresses and switches in sex ratios for any of the species studied, it was concluded that no explanation is readily available for the abrupt decrease of activity of one or the other sex, resulted in some hourly fluctuations.

Environment in Relation to Activity of Different Species

Seasonal changes in trapping results seem to be correlated with the intensity of individual activity in the case of *D. ordii*, but not with *D. merriami*. Movement was also demonstrated to change as the season progressed, and was most extensive in June. The percentages of animals that were captured on consecutive hours during one night also changed and were highest during July. The percentages of animals that were captured on consecutive nights were greatest in July. Animals apparently moved farther in June, but more were out two or more times in a shorter range in July. Seasonal variations can generally be explained in terms of changing population densities for most species. However, as was pointed out in the case of *D. merriami* and *D. ordii*, variations might be at least partially due to changes in activity. Hibernation and aestivation also influences seasonal variations in trapping activity, as was pointed out in the case of *P. longimembris*.

Light appeared to be the environmental factor primarily responsible for triggering activity. Figures 16-28 demonstrate that *A. leucurus* ceased to be active and *D. merriami*, *D. ordii*, *D. microps*, and *P. longimembris* initiated their activity at sunset. From February to June there was a difference between sunset and sunrise of 8.0 to 5.5 hours, respectively. Regardless of this 5.2 hour variation from February to June, activity was initiated at sunset or soon after throughout the time of this study.

Environmental factors such as temperatures, moonlight, wind, and light intermittent rains had little influence on daily trapping results of *D. ordii* and *D. merriami*. In one case of *D. ordii* a rather sharp decrease in numbers was shown to be a result of decreased activity on the part of females. Other cases were noted in which changes in the activity of one sex resulted in hourly and/or daily fluctuations. Hourly fluctuations of *P. longimembris* may be partially explained in terms of their negative response to rains and changes in moonlight. Bartholomew and Cade (1957) demonstrated that *P. longimembris* hibernated within 24 hours when food was not available, but if it were available only a few hibernated in several days.

HOME RANGE

The concept of home range and other methods of measuring animal movement have been considered as important behavior characteristics of mammals for many years. Some interesting studies were made by Brant (1962), Burt (1940), Calhoun and Casby (1958), Dice and Clark (1953), Harrison (1958), Hayne (1949b), Jackson and Strecker (1962), Jorgensen and Tanner (1963), Mohr and Stumpf (1964), Spencer and Davis (1950), Stumpf and Mohr (1962), Tanaka, Sugiyama and Teramuro (1958), Tinkle, McGregor and Sumner (1962), and others. Some of the advantages and disadvantages inherent in the methods used to determine home range have been discussed by Hayne (1949b), Calhoun and Casby (1958), and Jorgensen and Tanner (1963). The home range concept must include relative intensity of usage if it is to furnish data useful in analyzing population data. Uniform usage, regardless of the shape of the area, is not realistic and must be reevaluated if specific interactions are considered. A round home range is equally as unrealistic but provides the most convenient data that can be applied to population density determinations.

Another aspect of home range that is frequently neglected is the time interval required to gather the field data. It is becoming increasingly evident as we continue to work with small mammal interactions that this factor will have to be evaluated more completely.

Home-range data have been used by us in several ways. They were used in our density determinations which were in turn used to evaluate the effects plant communities have on small mammal distribution. They were also considered in evaluating spatial interactions of individuals Home range or more precisely "range of movement" was used to measure the effects of nuclear weapons testing on small mammals by White and Allred (1961).

METHODS

Home ranges were measured in ten grids which were situated in different plant associations at the test site. The trapping design of these grids is described by Allred, Beck and Jorgensen (1963a). Since several grids had small mammal species in common, home ranges were measured several times for certain species. In other cases the home range of a given species was measured in only one grid. Vegetation analyses were made for most of the grids and these are summarized in Table 10. The grids and the species measured in each are summarized in Table 11. These plant analyses were taken with the method described by Jorgensen (1963).

Table 10. Percentage of ground cover and composition of trapping grids at the test site.

Plant Species	Grids[a]									
	12A[b]	12E[b]	10D	6A	5A	5E	4A	1F[b]	JA	TA
Percentage ground cover	X	X	25.4	21.0	11.4	11.9	19.6	X	17.4	31.0
Artemisia spinescens			0.9	3.0		0.5	3.4			
Artemisia tridentata	X	X								67.5
Atriplex canescens						2.7	6.4			
Atriplex confertifolia				60.7		0.3				
Bromus rubens								X		
Cercocarpus ledifolius	X	X								
Chaenactis stevioides								X		
Coleogyne ramosissima	X	X	64.2						30.0	
Cowania stansburiana	X	X								
Dalea polyadenia					3.3	7.0			1.2	
Ephedra nevadensis			2.8		6.3				15.2	7.9
Ephedra viridis	X	X								
Eriogonum sp.								X		
Eurotia lanata			0.1	10.6		2.7	15.1		1.9	
Franseria dumosa					20.2				9.9	
Grayia spinosa			24.2		7.9	17.4	53.8		9.9	1.6
Hymenoclea salsola			2.0		9.5				0.4	
Juniperus osteosperma	X	X								
Kochia americana				25.7						
Larrea divaricata					44.9				5.1	
Lycium andersonii			2.1		7.9	8.2	15.4		9.5	
Lycium pallidum						60.0			9.8	
Mirabilis pudica						0.9		X		
Oryzopsis hymenoides			2.4			0.3	3.7			
Pinus monophylla	X	X								
Quercus gambelii	X	X								
Salsola kali								X		
Sitanion hansenii			0.5				0.4			2.5
Stipa comata	X	X					1.8			
Tetradymia axillaris			0.5						1.3	
Tetradymia glabrata			0.3							
Stipa speciosa										20.2
Haplopappus cooperi									0.3	0.1
Chrysothamnus viscidiflorus									2.8	0.2
Krameria parvifolia									0.1	
Dalea fremontii									1.3	
Lepidium fremontii									0.6	
Stanleya pinnata									0.7	

[a]Refer to Allred, Beck and Jorgensen (1963b) for location of each grid. 12A - Pinyon-Juniper (disturbed by testing), 12E - Pinyon-Juniper, 10D - Coleogyne, 6A - Atriplex-Kochia, 5A - Larrea-Franseria, 5E - Larrrea-Franseria (*Lycium pallidum* association), 4A - Grayia-Lycium, 1F - Salsola (disturbed by testing), JA - Larrea-Franseria (mixed plant association), TA - Coleogyne (*Artemisia tridentata* association).
[b]Vegatation analysis data are not available for these grids.

Table 11. Summary of the grids from which the home ranges of small mammals were determined.

Grid	Biotic Community	No. of Trapping Stations	Size of Area in Ares[a]	Months Operated	Small Mammal Species Included[b]									
					Amm leu	Dip mer	Dip mic	Dip ord	Ony tor	Per man	Per tru	Prg for	Prg lon	Prg par
1F	Salsola	144 (12x12)	624 (15.6)	15		X		X						
4A[c]	Grayia-Lycium	144 (12x12)	624 (15.6)	17	X	X	X			X			X	
5A[c]	Larrea-Franseria	144 (12x12)	624 (15.6)	18	X	X						X	X	
5E[c]	Larrea-Franseria	144 (12x12)	624 (15.6)	15	X	X	X					X	X	
6A[c]	Atriplex-Kochia	144 (12x12)	624 (15.6)	18			X							
10D[c]	Coleogyne	144 (12x12)	624 (15.6)	29	X	X	X		X	X			X	
12A	Pinyon-Juniper	60 (10x6)	232 (5.8)	9						X	X			
12E	Pinyon-Juniper	60 (10x6)	232 (5.8)	9						X	X			X
JA	Mixed	144 (12x12)	624 (15.6)	18	X	X	X		X			X	X	
TA	Coleogyne	144 (12x12)	624 (15.6)	13	X	X			X	X			X	X

[a]Acres are included in parentheses.

[b]Amm leu - *Ammospermophilus leucurus*, Dip mer - *Dipodomys merriami*, Dip mic - *Dipodomys microps*, Ony tor - *Onychomys torridus*, Per man - *Peromyscus maniculatus*, Per tru - *Peromyscus truei*, Prg for - *Perognathus formosus*, Prg lon - *Perognathus longimembris*, Prg par - *Perognathus parvus*.

[c]Grids in which one half of the traps were removed after almost all of the small mammals had been marked.

Note on Table 11 that 12A and 12E were trapped for only 9 months. During the winter months these grids were not accessible and consequently were not trapped for a period of four months. All others were operated for at least one year on a continuous basis and one (IOD) for more than two years.

Each of the grids was trapped for three consecutive days each month. During this time the animals were recorded with the following information: station (all stations were stationary), date, species, stage of development (adult or subadult), sex, lactating or sexually active (whenever clearly discernible), and mark (a system of clipped ears and toes was used). After these data had been recorded, the animal was then released at the station where it was trapped. The number of traps was decreased in several of the grids by removing every other trap after most of the small mammals had apparently been marked (Table 11).

These data were all placed on IBM punch cards and the analysis for home range made with the IBM 650 computer. The density probability function as described by Dice and Clark (1953) and Jorgensen and Tanner (1963) was used in determining the size of home range. Rather than pooling recapture data which could be graphically measured, as was done by Jorgensen and Tanner (1963), the apparent center of activity and recapture radii (distance from the apparent center of activity to points of recapture) were computed with

$$y_n = [(x_n - \bar{x})^2 + (y_n - \bar{y})^2]^{\frac{1}{2}}$$

where $(\bar{x},\bar{y})$ is the recapture center and (x_n,y_n) is the position of the nth capture (recapture locus).

After the distance from the recapture center to some point inside which 95% of the recaptures would be expected to occur was computed, those recapture loci that fell outside of this expectation were eliminated and the distance recalculated at the .95 probability. This was done to avoid the distortion and unnecessary extension of home range resulting from momentary forays by individuals. Another limitation placed on these data was that an individual must be recaptured two or more times in at least two different stations. No restrictions were placed on the individuals that were trapped in the traps on the margins of the grids only.

Results

Home range estimates for the species varied among the different communities in which they were determined. These results are summarized on Table 12. An analysis of variance was used to determine (1) if there were any significant differences in the sizes of home ranges among the study grids, and (2) if there were differences in the sizes of home ranges between the sexes. These results are presented in Tables 13 and 14, respectively. In only one case was there a significant difference ($P<.05$) among the study areas (*A. leucurus*). Although rather wide differences were apparent among the grids for several of the small mammal species, the variance was usually so great within each grid that significant differences were not evident. This was also true between the sexes where no significant differences were observed.

It is apparent in Table 12 that several of the studies have only one sex analyzed. In those cases and for the sake of the analysis of variance, substitute values were computed (Li, 1957) and inserted. This seemed justified since even though both sexes were not captured sufficient times to qualify for analysis, they were present and occasionally trapped in the grids.

It is possible that the recapture center for a certain individual could be located directly on the margin of the grid, causing many of the radii to be extended beyond the grid margins by a distance equal to the length of the recapture radius. The actual area trapped is consequently larger than that indicated in Table 10. These adjusted results are presented in Table 15. The males recapture radii extended the grids by an average of 96% while females averaged 79%. An examination of Table 14 also indicates that the average home range of males is slightly larger, but not significantly so when the variance is analyzed ($P<.05$). Although the grids were extended the full length of the recapture radii, few of the recapture centers were located precisely on the margin; thus, the adjusted grid area may be slightly large.

The sizes of home ranges with respect to the grid size for each species with sufficient captures and recaptures to make a reliable estimate are plotted on Figures 30-34. These are all on 624 are (15.6 acre) grids with the exception of Figure 34, which is on 232 are (5.8 acre) grids.

When this method was used to compute home ranges, it was thought it would provide some means for computing a quantitative value for individual interactions in space. After the home ranges were plotted on a grid, it became apparent they were so large that in most cases each home range included the centers of many others. For this reason interaction was not estimated from an analysis of the overlap of home ranges.

Table 12. Summary of home-range data for small mammals, with recapture radius within which 95% of the recaptures would be expected to occur using normal distribution.

		Males				Females			
Species	Grid[a]	Number of Specimens	Avg Captures per Specimen	95% Radius in Meters[b]	Area in Ares[c]	Number of Specimens	Avg Captures per Specimen	95% Radius in Meters[b]	Area in Ares[c]
Ammospermophilus leucurus	4A	5	3.8	114 (375)	406 (10.11)	1	3.0	81 (265)	202 (5.06)
	5A	—[d]	—	—	—	2	3.0	109 (358)	370 (9.21)
	5E	1	3.0	62 (204)	120 (3.00)	—[d]	—	—	—
	10D	4	3.8	145 (478)	659 (16.47)	2	4.5	170 (558)	898 (22.46)
	JA	16	3.9	113 (371)	397 (9.93)	14	4.4	90 (295)	251 (6.28)
	TA	10	4.4	132 (432)	538 (13.46)	8	4.6	113 (370)	395 (9.87)
Dipodomys merriami	1F	71	5.5	74 (244)	172 (4.29)	64	6.3	73 (238)	161 (4.09)
	4A	5	5.0	175 (575)	954 (23.85)	8	4.3	50 (164)	78 (1.91)
	5A	17	4.8	116 (381)	419 (10.47)	23	5.9	62 (203)	119 (2.97)
	5E	10	5.1	105 (343)	339 (8.48)	15	6.5	70 (230)	153 (3.82)
	10D	2	5.0	66 (216)	134 (3.36)	—[d]	—	—	—
	JA	1	18.0	85 (280)	226 (5.65)	2	3.5	55 (182)	96 (2.39)
	TA	10	5.9	114 (374)	403 (10.08)	9	5.6	126 (125)	521 (13.03)
Dipodomys microps	4A	14	4.5	100 (327)	308 (7.71)	12	4.7	78 (256)	189 (4.73)
	5E	15	6.5	61 (200)	115 (2.88)	8	7.4	56 (184)	98 (2.44)
	6A	45	6.0	78 (255)	188 (4.69)	23	5.3	63 (208)	125 (3.12)
	10D	66	4.8	87 (285)	234 (5.86)	55	5.2	77 (252)	183 (4.58)
	JA	28	5.5	66 (218)	137 (3.43)	23	7.7	63 (208)	125 (3.12)
	TA	—[d]	—	—	—	1	5.0	35 (114)	38 (0.94)

Dipodomys ordii	1F	26	4.5	52 (172)	85 (2.13)	23	5.4	76 (250)	180 (4.51)
Onychomys torridus	10D	3	3.7	133 (437)	551 (13.77)	1	3.0	160 (526)	798 (19.95)
	JA	—[d]	—	—	—	2	4.5	123 (404)	471 (11.77)
	TA	3	7.0	169 (553)	882 (22.06)	7	4.6	139 (455)	597 (14.93)
Perognathus formosus	5A	1	3.0	108 (355)	364 (9.09)	3	5.0	41 (133)	51 (1.28)
	5E	9	5.0	85 (279)	224 (5.61)	3	6.7	46 (150)	65 (1.62)
	JA	35	7.4	67 (221)	141 (3.52)	21	6.9	65 (213)	131 (3.27)
Perognathus longimembris	4A	18	4.1	80 (264)	201 (5.03)	21	3.5	41 (136)	53 (1.33)
	5A	15	3.8	101 (330)	314 (7.85)	6	3.5	74 (243)	170 (4.26)
	5E	16	4.0	80 (261)	196 (4.91)	10	3.4	82 (270)	210 (5.26)
	10D	5	3.4	102 (333)	320 (7.99)	4	3.8	46 (150)	65 (1.62)
	JA	28	4.8	43 (141)	57 (1.43)	33	5.9	37 (121)	42 (1.06)
	TA	15	5.1	52 (172)	85 (2.13)	17	4.8	52 (170)	83 (2.08)
Perognathus parvus	12E	3	4.3	47 (153)	68 (1.69)	—[d]	—	—	—
	TA	2	3.0	61 (201)	116 (2.91)	1	4.0	56 (185)	99 (2.47)
Peromyscus maniculatus	10D	8	5.0	173 (567)	928 (23.19)	3	9.7	94 (308)	274 (6.84)
	12A	16	5.9	60 (197)	112 (2.80)	17	4.6	60 (197)	112 (2.80)
	12E	14	5.6	78 (256)	189 (4.73)	5	7.0	64 (211)	129 (3.22)
	TA	2	3.0	65 (214)	132 (3.30)	1	3.0	104 (342)	310 (7.75)
Peromyscus truei	12A	2	3.0	47 (155)	51 (1.27)	2	3.0	37 (121)	42 (1.06)
	12E	5	6.0	63 (206)	122 (3.06)	4	5.3	55 (180)	94 (2.34)

[a]1F - Salsola, 4A - Grayia-Lycium, 5A - Larrea-Franseria, 5E - Larrea-Franseria (*Lycium pallidum* association), 6A - Atriplex-Kochia, 10D - Coleogyne, 12A - Pinyon-Juniper (disturbed by testing), 12E - Pinyon-Juniper, JA - Larrea-Franseria (mixed plant association), TA - Coleogyne (*Artemisia tridentata* association).
[b]Foot values are included in parentheses.
[c]Acre values are included in parentheses.
[d]None was collected three or more times in at least two stations.

Table 13. The average home ranges of small mammals among the plant communities.

Grid and Biotic Community	Average Area for each Species (Ares)[c]									
	Amm leu	Dip mer	Dip mic	Dip ord	Ony tor	Prg for	Prg lon	Prg par	Per man	Per tru
1F Salsola		168 (4.20)		133 (3.33)						
4A Gravia-Lycium	304 (7.60)	516 (12.90)	249 (6.23)				127 (3.18)			
5A Larrea-Franseria	384 (9.60)	269 (6.73)				208 (5.20)	242 (6.05)			
5E Larrea-Franseria	196 (4.90)	246 (6.15)	107 (2.68)			145 (3.63)	203 (5.08)			
6A Atriplex-Kochia			157 (3.93)							
10D Coleogyne	779 (19.48)	148 (3.70)	209 (5.23)		675 (16.88)		193 (4.83)		601 (15.03)	
12A Pinyon-Juniper									112 (2.80)	47 (1.18)
12E Pinyon-Juniper								76 (1.90)	159 (3.98)	108 (2.70)
JA Larrea-Franseria	324 (8.10)	161 (4.03)	131 (3.28)		533 (13.33)	136 (3.40)	50 (1.25)			
TA Coleogyne	467 (11.68)	462 (11.55)			740 (18.50)		85 (2.13)	108 (2.70)	221 (5.53)	
LSD .05	268	n.s.[a]	n.s.	n.c.[b]	n.s.	n.s.	n.s.	n.c.	n.s.	n.c.
LSD .01	433	n.s.	n.s.	n.c.	n.s.	n.s.	n.s.	n.c.	n.s.	n.c.

[a]Not significant.
[b]Not computed because of insufficient data.
[c]Amm leu - *Ammospermophilus leucurus*, Dip mer - *Dipodomys merriami*, Dip mic - *Dipodomys microps*, Dip ord - *Dipodomys ordii*, Ony tor - *Onychomys torridus*, Prg for - *Perognathus formosus*, Prg lon - *Perognathus longimembris*, Prg par - *Perognathus parvus*, Per man - *Peromyscus maniculatus*, Per tru - *Peromyscus truei*. Numbers in parentheses are areas in acres.

Table 14. Differences in the average home ranges of male and female small mammals.

Species	Average Area for each Species (Ares)[a]		
	Male	Female	Difference
Ammospermophilus leucurus	504 (12.60)	477 (11.93)	27 (0.68)
Dipodomys merriami	378 (9.45)	185 (4.63)	193 (4.83)
Dipodomys microps	491 (12.28)	360 (9.00)	131 (3.28)
Dipodomys ordii	85 (2.13)	180 (4.50)	-95 (-2.38)
Onychomys torridus	676 (16.90)	622 (15.55)	54 (1.35)
Perognathus formosus	243 (6.08)	82 (2.05)	161 (4.03)
Perognathus longimembris	196 (4.90)	104 (2.60)	92 (2.30)
Perognathus parvus	92 (2.30)	92 (2.30)	0 (0.0)
Peromyscus maniculatus	340 (8.50)	206 (5.15)	134 (3.35)
Peromyscus truei	87 (2.18)	68 (1.70)	19 (0.48)

[a]Numbers in parentheses are areas in acres.

To provide an estimate of their intraspecific interactions, the number of recapture centers that would fit on a linear transect through the computed radius of respective home ranges was determined. This determination was made by measuring the distance between each recapture center and its nearest neighbor. Measurements were made between male and male, female and female, and male and female. After these measurements had been taken, the average was computed and divided into the recapture radius to determine the numbers of recapture centers that would be expected to occur within any given individual's recapture radius. This provided a contrast of the distance between recapture centers of nearest neighbors and recapture radii. The results of this analysis are presented in Table 16.

The most apparent observation that can be made from this analysis is that the number of recapture centers per recapture radius increases as the density of recapture centers increases on each grid. These observations suggest that the size of home range is not entirely dependent on the density of organisms measured, thus adding

Table 15. Summary of the grid size adjustment, resulting from marginal extensions by the distance of the recapture radii.

Species	Study[a]	Recapture Radii (m)[b] P<.05		Adjusted Grid Area (Ares)[c]		Percentage Increase	
		Male	Female	Male	Female	Male	Female
Ammospermophilus leucurus	4A	114 (374)	81 (266)	2304 (57.6)	1713 (42.8)	269	74
	5A	—[d]	109 (358)	—	2209 (55.2)	—	254
	5E	62 (203)	—	1413 (35.3)	—	126	—
	10D	145 (476)	170 (558)	2937 (73.4)	3504 (87.6)	370	461
	JA	113 (371)	90 (295)	2284 (57.1)	1866 (46.7)	266	199
	TA	132 (433)	113 (371)	2662 (66.6)	2284 (57.1)	326	266
Dipodomys merriami	1F	74 (243)	73 (239)	1600 (40.0)	1584 (39.6)	156	153
	4A	175 (574)	50 (164)	3624 (90.6)	1259 (31.5)	480	98
	5A	116 (380)	62 (203)	2342 (58.6)	1413 (35.3)	275	126
	5E	105 (344)	70 (230)	1274 (31.9)	1536 (38.4)	104	146
	10D	66 (216)	—	1474 (36.9)	—	136	—
	JA	85 (279)	55 (180)	1780 (44.5)	1310 (32.8)	185	109
	TA	114 (374)	126 (413)	2304 (57.6)	2540 (63.5)	269	307
Dipodomys microps	4A	100 (328)	78 (256)	2043 (51.1)	1664 (41.6)	218	166
	5E	61 (200)	56 (184)	1398 (55.0)	1324 (33.1)	124	112
	6A	78 (256)	63 (207)	1664 (41.6)	1428 (35.7)	166	228
	10D	87 (285)	77 (253)	1814 (45.4)	1648 (41.2)	190	264
	JA	66 (216)	63 (207)	1474 (36.9)	1428 (35.7)	136	228
	TA	—	35 (115)	—	1036 (25.9)	—	66
Dipodomys ordii	1F	52 (171)	76 (249)	1267 (31.7)	1632 (40.8)	103	161
Onychomys torridus	10D	133 (436)	160 (525)	2683 (67.1)	3271 (81.8)	330	424
	JA	—	123 (403)	—	2480 (62.0)	—	297
	TA	169 (554)	139 (456)	3481 (87.0)	2509 (62.7)	457	350
Perognathus formosus	5A	108 (354)	41 (134)	2190 (54.8)	1556 (38.9)	251	78
	5E	85 (279)	46 (151)	1780 (44.5)	1183 (29.6)	185	89
	JA	67 (220)	65 (213)	1490 (37.3)	1459 (36.5)	138	133
Perognathus longimembris	4A	80 (262)	41 (134)	1697 (42.4)	1115 (27.9)	171	78
	5A	101 (331)	74 (243)	2061 (51.5)	1600 (40.0)	230	156
	5E	80 (262)	82 (269)	2061 (51.5)	1730 (43.3)	171	177
	10D	102 (335)	46 (151)	2079 (52.0)	1183 (29.6)	233	89

	JA	43 (141)	37 (121)	1112 (28.6)	1062 (26.6)	83	70
	TA	52 (171)	52 (171)	1267 (31.7)	1267 (31.7)	103	103
Perognathus parvus	12E	47 (154)	—	624 (15.6)	—	121	—
	TA	61 (200)	56 (184)	1398 (35.0)	1324 (33.1)	124	112
Peromyscus maniculatus	10D	173 (567)	94 (308)	3576 (89.4)	1936 (48.4)	473	210
	12A	60 (197)	60 (197)	838 (21.0)	838 (21.0)	197	197
	12E	78 (256)	64 (210)	955 (23.9)	885 (22.1)	239	214
	TA	65 (213)	104 (341)	1459 (36.5)	2116 (52.9)	133	239
Peromyscus truei	12A	47 (154)	37 (121)	624 (15.6)	591 (14.8)	121	109
	12E	63 (207)	55 (180)	873 (21.8)	780 (19.5)	209	176

[a]1F - Salsola, 4A - Grayia-Lycium, 5A - Larrea-Franseria, 5E - Larrea-Franseria, 6A - Atriplex-Kochia, 10D - Coleogyne, 12A - Pinyon-Juniper, 12E - Pinyon-Juniper, JA - Larrea-Franseria, TA - Coleogyne.
[b]Numbers in parentheses are distances in feet.
[c]Numbers in parentheses are areas in acres.
[d]None was collected three or more times in at least two stations.

Table 16. Number of recapture centers along the recapture radii of home ranges.

Species	Study[a]	Average Distance (m) between Nearest Neighbors			Recapture Centers per Recapture Radii	
		Male[b] to Male	Female to Female	Female to Male	Male to Male	Female to Female
Ammospermophilus leucurus	JA	37.08 (122)	38.56 (126)	41.87 (137)	3.07	2.10
	TA	48.68 (160)	56.93 (187)	40.28 (132)	2.71	1.98
Dipodomys merriami	1F	14.96 (49)	16.72 (55)	13.51 (44)	4.94	4.36
	5A	31.00 (102)	22.71 (74)	33.52 (110)	3.74	2.73
	5E	42.86 (141)	52.70 (173)	43.21 (142)	2.44	1.32
	TA	53.07 (174)	67.10 (220)	42.42 (139)	2.14	1.87
Dipodomys microps	10D	15.94 (52)	17.43 (57)	16.52 (54)	5.45	4.41
	6A	20.61 (68)	28.75 (94)	22.23 (73)	3.87	2.19
	JA	28.70 (94)	28.88 (95)	31.02 (102)	2.29	1.77
	5E	28.50 (93)	63.02 (207)	36.06 (118)	2.14	.89
	4A	46.86 (154)	39.34 (129)	41.93 (138)	2.13	1.98
Dipodomys ordii	1F	48.89 (160)	37.30 (122)	53.06 (174)	1.06	2.03
Perognathus formosus	JA	24.13 (79)	36.69 (120)	24.71 (81)	2.77	1.79
Perognathus longimembris	JA	32.86 (108)	28.14 (92)	23.27 (76)	1.30	1.31

	4A	33.51 (110)	33.26 (109)	32.07 (105)	2.39	1.23
	5E	34.25 (112)	55.10 (181)	28.15 (92)	2.33	1.49
	5A	41.97 (138)	43.92 (144)	40.03 (131)	2.41	1.68
	TA	36.38 (119)	36.73 (120)	26.95 (88)	1.43	1.34
Peromyscus maniculatus	12A	19.92 (65)	23.74 (78)	17.44 (57)	3.01	2.53
	12E	28.79 (94)	51.24 (168)	32.04 (105)	2.71	2.69

[a]1F - Salsola, 4A - Grayia-Lycium, 5A - Larrea-Franseria, 5E - Larrea-Franseria, 6A - Atriplex-Kochia, 10D - Coleogyne, 12A - Pinyon-Juniper, 12E - Pinyon-Juniper, JA - Larrea-Franseria, TA - Coleogyne.
[b]Numbers in parentheses are distances in feet.

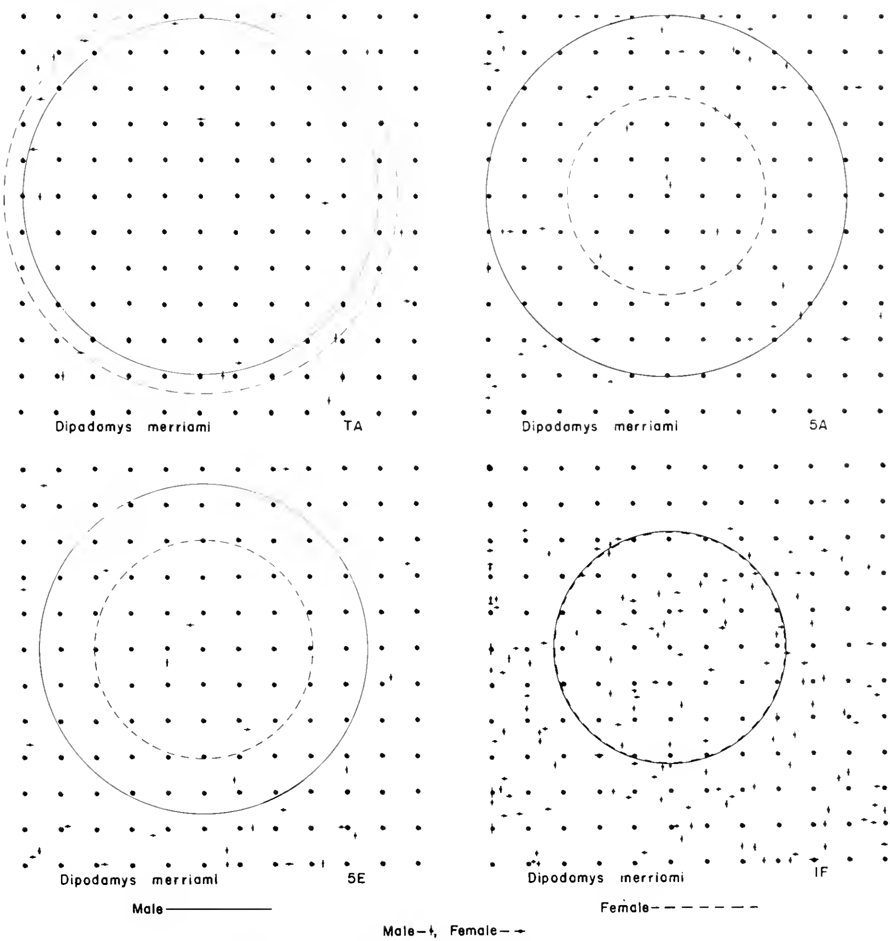


Figure 30. Recapture centers and home ranges of *Dipodomys merriami*.

support to our contention that competition for space among desert species of small mammals is relieved somewhat by their behavior.

DISCUSSION OF HOME RANGE

Home range was considered from the point of view of where individual animals were captured and recaptured within grids with stationary trapping stations. No effort was made to move the traps to other locations or to alter the baiting procedure from one month to the next. It is possible, therefore, that some "trap-happiness" may have developed. But, since the grids were trapped for only three days each month, it is doubtful that the habit would have been easily detected.

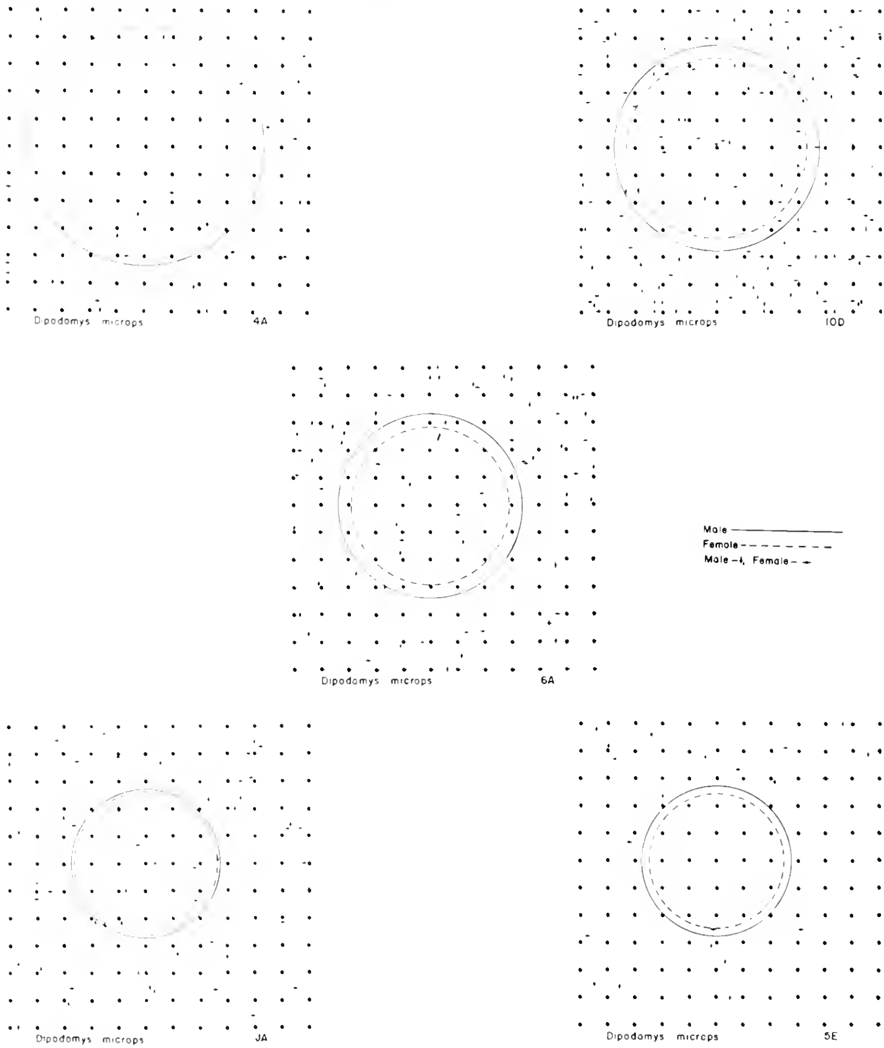


Figure 31. Recapture centers and home ranges of *Dipodomys microps.*

Another problem that arises from this type of an approach is the time intervals in which the data were actually gathered. Using the density probability method of home range determination over a long period of time would not allow detection of small changes in the range. For this reason the home ranges could actually be smaller at any particular shorter time interval than our results indicate. We attempted to adjust for this by excluding those observations that fell outside what would be expected ($P < .05$).

Although home range for an animal is certainly subject to change from environmental stresses, only population density and trap density have been convincingly shown to be important factors. Such factors as sexual activity, location,

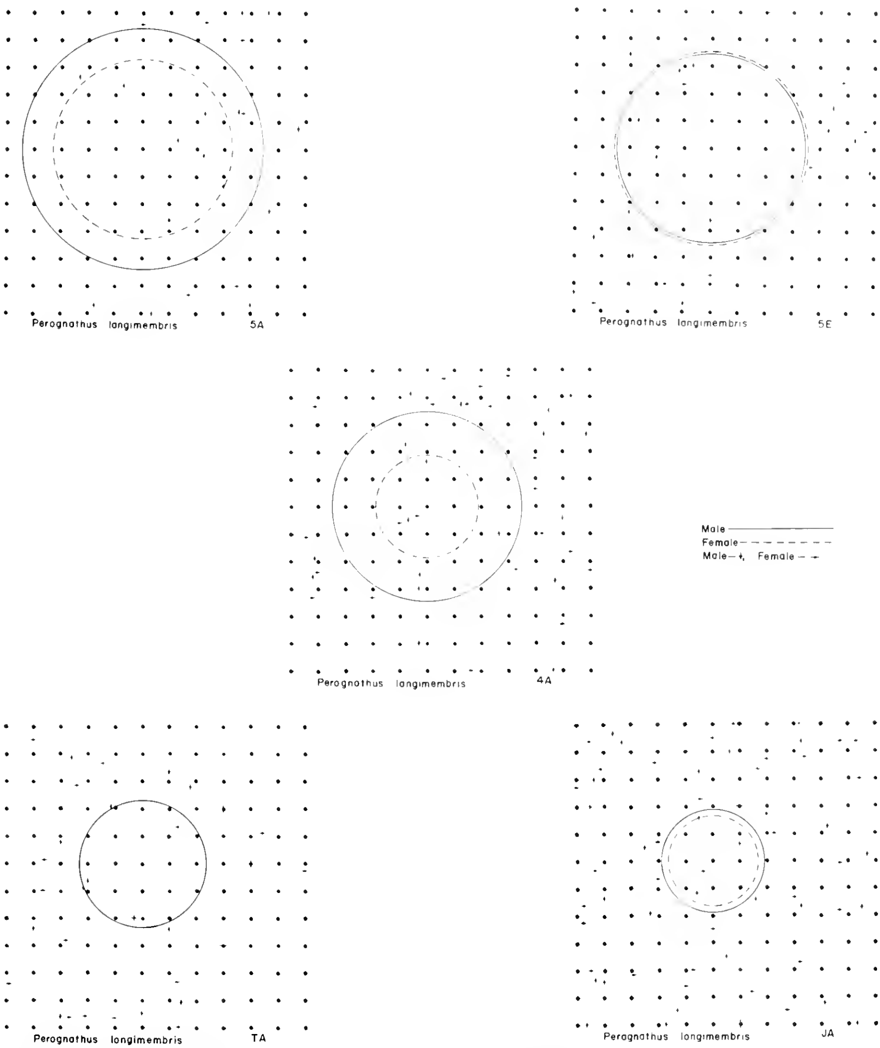


Figure 32. Recapture centers and home ranges of *Perognathus longimembris.*

wintering activity, etc. would likely have an influence on the animals' wandering habits. Our data indicate that although short wanderings may have occurred, extensive wandering was rather rare and was not included in the analyses. Rather than resulting in a change of the actual center of the home range, it is more likely that the extent of their wanderings would increase, causing the home range to increase. It could be argued that computing home range over such a long period of time would increase home range, and this would certainly be true if the actual center were to change. But if only the range were to change, a long time period would do no more than measure the largest movement. We consider our data to represent the largest home range that would be expected and that any shorter time period would yield data showing home ranges equal to or less than ours. For the purpose we have used home range (computation of small mammal densities) and possible intraspecific interaction, this seemed to be ade-

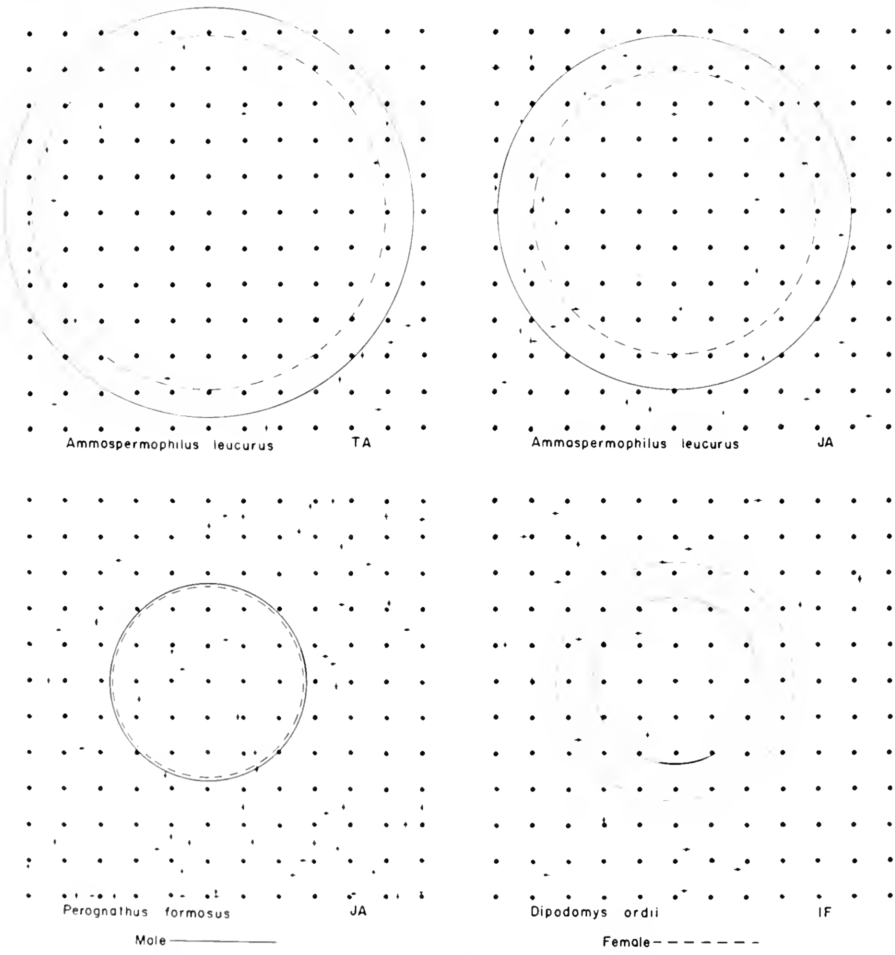


Figure 33. Recapture centers and home ranges of *Ammospermophilus leucurus*, *Perognathus formosus*, and *Dipodomys ordii*.

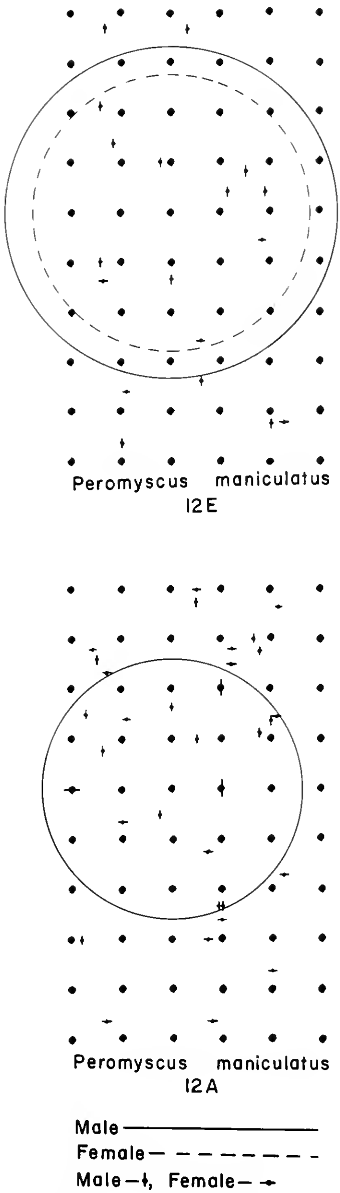


Figure 34. Recapture centers and home ranges of *Peromyscus maniculatus*. Where only one recapture radius is presented (12A), both sexes had the same radius.

quate. We must state, however, that if one is interested in other factors such as gene flow within the population, a short time measurement during the breeding season would likely yield the most useful data.

Another factor which influences home range data is the margins of the grids. In this case the margins have the effect of limiting the recapture radii, causing the average home range to appear smaller. When home ranges are as large as they were generally found to be during our work, it is difficult to assess the influence the margins may have on the average home range. All of the recaptures were included in our analyses, except for those excluded for reasons discussed in the methods; consequently, the average home ranges may be computed somewhat smaller than they actually are.

The influence of the border on home ranges has the effect of being distance dependent. As the recapture radii distances increase, the border of the grid becomes more of a factor, while smaller recapture radii are influenced less by this border. In this sense it is probable that large computed home ranges are actually underestimated more than those which are smaller. Although the home ranges discussed in this report may at first appear large, if one considers all the factors contributing to the calculated estimates, it seems conceivable that they are underestimated rather than overestimated. One may wish to challenge these conclusions on the basis of short-term trapping results, but this is justifiable only if the short-term occurs during the time the animals have their longest ranges.

Some observations resulting from the analyses of home range are of interest in terms of behavior. Males generally range farther than the females, although this is not always true for individuals (Tables 12 and 14). The variation during the time of this study was rather high and would be expected to remain high when the data are gathered on a long-term basis. Note that though rather wide differences are observed between studies (Table 13), they were significant ($P<.05$) only in the case of *A. leucurus*, and in this case the samples were questionably low.

Interaction among species and individuals of the same species is sometimes thought to be rather specific, to the point of mutually excluding some species and individuals while establishing discrete territories. Daily activity demonstrated that this interaction may not be nearly as competitive as is sometimes thought. Home range also indicated that competition is not so specific in establishing territoriality in the classic

sense. In fact, as many as 5.45 average distances between the recapture centers of nearest neighbors may be found along one recapture radius (Table 16), thus allowing for tremendous interaction in space.

One must keep in mind the time interval in which these studies were made, for the longer the time the greater the number of recapture centers and the shorter the distance between them. This procedure, though used to illustrate interaction, would tend to overestimate the specific interaction at a given time. The extent of overestimation could not be determined from our work since it did cover a long time span, but it does illustrate that considerable interaction is present at all times. This interaction is thought to be such that it would not lead to the mutual exclusion of neighboring small mammals from a specific area.

SPECIES DISTRIBUTION

In keeping with one of our primary objectives at the Nevada Test Site, seasonal distribution of the small mammals and their distribution among the plant communities were investigated. This has been discussed, in part, by Allred, Beck and Jorgensen (1963a), Murdock (1961), and Allred and Beck (1963), but their work was focused essentially on the readily identifiable plant communities and the small mammals collected from within them. Similar studies were made by Hardy (1945), Burt (1934), and Hall (1946) in other localities.

The section of this paper entitled "Accounts of the Species" briefly listed the biotic communities occupied by the mammals. The present section will deal with two aspects of distribution—namely, the species distribution in the ecotone areas between major biotic communities and seasonal distribution within the established grids. The importance of plant species or complexes of plant species on small mammal distribution will also be discussed.

Methods

The trapping design and procedures for operating the ten grids as well as the arrangement and operation of the 136 transects have been described previously.

The density of small mammals in the grids was computed with the methods described by Hayne (1949a). The margins of the grids were expanded to include the .95 probability radius of a recapture from the estimated activity center. The expanded grid was used for the density estimate. Densities were estimated each month, based on a three-day trapping period.

Methods for computing densities when kill trapping techniques are used have been discussed by Leslie and Davis (1939), DeLury (1947), Hayne (1949a), Moran (1951), Zippin (1956), and Calhoun and Casby (1958). Perhaps the most difficult problem encountered in estimating populations is whether or not all animals are equally at risk. In most cases it is assumed they are, but Calhoun and Casby (1958) recognized the difficulty of this assumption and attempted to correct for home-range centers which were apparently different distances from the trap lines.

We simply used the recapture radii computed for each species in the various biotic communities to extend the trapped area, thus expanding the size of the area by the distance of their recapture radii on all four sides. For example, each of our 136 transects enclosed 39.6 ares (.99 acres), but to estimate the number of *D. merriami* it had to be expanded so as to include the total area apparently trapped. If the transect (5CX) were considered to be in a Larrea-Franseria community, the recapture radii for *D. merriami* in 5A (Larrea-Franseria, Table 13) was used to expand the actual area trapped to 421.6 ares (10.54 acres). This procedure was repeated in every instance in which density determinations were made.

One might question why the recapture radii were not integrated in the density estimate as described by Calhoun and Casby (1958). The principal reason was that the assumptions required for their procedures were not satisfied. In view of these difficulties it was felt it would be better to simply expand the trapping area rather than imply that these assumptions had been satisfied.

The problem of estimating the population size was also replete with difficulties. The principal problem centers, again, around whether or not the animals are equally at risk from day to day. If an animal used only fragments of its home range each day or if it were not trappable each day, the assumption that all are equally at risk is not valid. We have no data concerning

the first behavior problem, but our observations have led us to question the latter. When the species were pooled for analyses (i.e., all the new marks on the first, second, and third days in each grid), there was no indication of variable trappability. When the individual trapping periods each month were considered, however, wide variation was apparent. On the strength of this, some adjustment of the technique proposed by Calhoun and Casby (1958) was made in our computation techniques.

The population size was estimated with the following method:

$$n = c_1/(1\text{-}c_2/c_1)$$

n=initial population size.

c_1=total captured on the two days when most were trapped.

c_2=total captured on the remaining day when fewest were trapped.

This modification will obviously increase the slope of the regression curve and provide a more conservative estimate of the population. Due to the large fluctuations on individual trapping nights and since the second night frequently provided smaller estimates than the third, this adjustment seemed justifiable.

The vegetation in the vicinity of each of the 136 transects was evaluated, but no quantitative data recorded. The predominant plant species along with those that were rather common in the vicinity of each transect were recorded.

RESULTS

Spatial Distribution

Trapping results from the transects are presented in Table 17. These data were then grouped to examine the interactions of small mammals where they occur together. Correlation coefficients were computed for contrasting species to determine if any were significant (Table 18). From this table it is evident that for the most part there was no correlation in those cases where both species were present in the same area. The notable exceptions are *A. leucurus* vs. *D. microps* (r=.399) and *A. leucurus* vs. *P. longimembris* (r=.331).

The transects in which one species was present and another absent were examined (Table 19). Little can be observed from this table alone, but it does indicate which species were more universally distributed. For instance, *P. longimembris* was absent from an average of only 17% of the transects, *D. merriami* from 27%, *A. leucurus* from 32%, *D. microps* from 39%, *P. formosus* from 49%, and *O. torridus* from 52%. Other data such as slope and soil texture concerning the transects were then examined to determine if some explanation was available that would assist our analyses.

The vegetation was the first environmental factor examined. A summary of the vegetation and its relative abundance within each transect is presented in Table 20. A comparison of the small mammals and plant species can be seen from this table as the percentage of transects where both were present.

Two items of particular interest may be observed from Table 20. Certain plant species apparently had little or no effect on small mammal distribution because of their ubiquitous nature or general absence at the time surveys were made. *Atriplex confertifolia*, *Coleogyne ramosissima*, and *Ephedra nevadensis* are examples of those with a rather extensive distribution, while *Chaenactis fremontii*, *Dalea polyadenia*, and *Lepidium fremontii* are examples of species which are generally not abundant. The second observation that may be made from this table is the apparent influence certain plant species have on small mammal distribution. This does not necessarily indicate a causal effect and may result entirely from secondary influences. Examples of this type of interaction appear with *Atriplex canescens*, *Franseria dumosa*, and *Juniperus osteosperma*.

To facilitate a graphic correlation between small mammal abundance and relative abundance of predominant plant species, the predominant plant species were assigned the arbitrary value of two and the common species were assigned the value of one. The transects were pooled into three categories, the selection of which was essentially arbitrary, but based on major breaks in the decrease in small mammal density. With this type of analysis any correlation would be visible graphically even though its interpretation would be somewhat limited. Only the principally important plant species (that repeatedly occurred in each transect) were included in these analyses. These results are presented in Figures 35-40.

Some general trends may be observed from an examination of Figures 35-40. For instance, it appears that *A. leucurus* decreases as *Lycium andersonii*, *Larrea divaricata*, *Franseria dumosa*, and *Grayia spinosa* increase; and *Eurotia lanata*, *Atriplex confertifolia*, and *Lycium pallidum* decrease (Fig. 35).

Dipodomys merriami tends to decrease as *Larrea divaricata*, *Franseria dumosa*, and *Grayia spinosa* decrease; and *Eurotia lanata* increases (Fig. 36).

Table 17. Density of small mammals in the distribution transects.

Study	Biotic Community	Number per Acre[a,b]											
		Amm leu	Dip mer	Dip mic	Dip ord	Neo[c] lep	Ony tor	Per[c] cri	Per man	Per tru	Prg lor	Prg lon	Prg par
1CC	Grayia-Lycium			.59			.18					2.28	
2CB	Coleogyne	.14	.13	2.72			.49				.13	2.13	
2CC	Grayia-Lycium		.08	.09	.14		.21					1.75	
2CE	Coleogyne		.13						.02		1.87		
2CF	Coleogyne		.13	.21	.14		.06					1.36	
3CD	Coleogyne	.14	.13	.31		X		X			1.04	1.94	
3CE	Coleogyne	.05	.13	.55		X	.29	X	.02		.38	1.94	
3CF	Coleogyne	.10	.06	.94	.14		.29		.02			1.03	
3CG	Grayia-Lycium	.18	.38	1.28	.63		.23					1.58	
3CH	Mixed	.33		2.13								1.45	
3CI	Atriplex-Kochia			1.37								.05	
3CK	Salsola	.36	.91		.14		.07					.41	
3CL	Salsola				.28								
3CM	Salsola	.27										.14	
4CJ	Coleogyne		.88				.12				.13	2.38	
4CK	Coleogyne		1.13		.14		.12					1.25	
5CU	Larrea-Franseria	.08	.09	.14								.19	
5CV	Larrea-Franseria		.66				.61				.11	2.41	
5CW	Mixed	.13	.47									2.69	
5CX	Larrea-Franseria		.28									1.30	
5CY	Larrea-Franseria	.13		.28								.88	
5CZ	Larrea-Franseria	.13	.09	.28							.11	1.67	
5HA	Larrea-Franseria		.47				.61				1.14	.97	
5HB	Mixed	.08	.12	.38			.61				.90	1.82	
5HC	Mixed		.24	.38							2.29	.20	
5HD	Larrea-Franseria	.23	.19	.56				X			.56	.48	
5HE	Larrea-Franseria	.08		.42			.61				.23	.39	
5HF	Larrea-Franseria		.19						.02				
5HG	Larrea-Franseria		1.71								1.47	.19	
5HH	Larrea-Franseria		.38	.14				X			2.28		
5HI	Larrea-Franseria	.16	.78								.79	.96	
5HJ	Larrea-Franseria	.08	.59									.39	
5HK	Larrea-Franseria	.16		.28							.23	.51	
5HL	Larrea-Franseria			.14							.11	.48	

5HM	Larrea-Franseria		.09								.11	.48
6CR	Coleogyne	.09		.62			.06	X			1.88	.45
6CS	Grayia-Lycium	.36	.60	1.04			.14				.75	1.76
6CT	Larrea-Franseria	.16	.10	.97							.45	1.35
6CU	Coleogyne	.19	1.04	2.24			.18	X			.67	1.39
6CV	Grayia-Lycium	.09	.23	.85			.31	X			.25	2.33
6CW	Grayia-Lycium	.82	.23	2.07			.26			.19		2.53
6CX	Grayia-Lycium	.41	.60									1.93
6CY	Grayia-Lycium	.74					.47					2.04
6CZ	Coleogyne	.09	.50				.12	X			3.13	
6FA	Coleogyne	.28			.14	X	.06	X			1.39	.34
6FB	Coleogyne	.05	.78			X	.12	X			2.03	.79
6FC	Mixed	.17	.24			X	.07				.13	1.44
6FD	Atriplex-Kochia		.53									
6FE	Atriplex-Kochia	.09		.14				X				.11
6FF	Mixed	.08		1.30			.21	.07				3.25
6FG	Larrea-Franseria	.23	.68	.14							.51	1.12
6FH	Larrea-Franseria	.23	.29	.14							1.35	
6FI	Larrea-Franseria	.23	.09	.56				X			.79	
7CC	Salsola	.09	.34									.14
7CD	Salsola		.23	.09								.27
7CE	Salsola	.19	.34	.51							.25	.57
8CC	Salsola				.28				.14			.14
9CB	Salsola	.23	.68	.38								1.49
9CC	Salsola					X						
9CD	Mixed	.08		.76			.06					3.81
9CE	Salsola		.34					X				1.22
9CF	Salsola	.27		.19								1.35
9CG	Salsola	.09										
10CK	Salsola		.11				.07					
10CL	Salsola	.36	.34		.28		.07					.40
10CM	Coleogyne		1.38									1.70
10CN	Grayia-Lycium	.27		.09			.14					2.97
12CH	Coleogyne			.41		X	.12		.37		1.34	
400CA	Larrea-Franseria		.38									1.06
400CB	Larrea-Franseria	.08	.59									.95
400CC	Larrea-Franseria		1.16	.14								1.03
400CD	Larrea-Franseria		.68									.88
400CE	Larrea-Franseria		.59									.58
400CG	Larrea-Franseria	.40	.19								.51	2.20
400CH	Larrea-Franseria	.16										1.03
400CI	Larrea-Franseria	.08										
400CJ	Larrea-Franseria	.16									.23	
401CA	Larrea-Franseria	.31	1.62	.56				X			.45	1.48

401CB	Mixed	.25	1.79									1.80	
401CC	Larrea-Franseria	1.06	.29				.21				.68	69	
401CD	Larrea-Franseria	.27	.29	.88			.35					2.21	
401CE	Mixed	.68	.48	1.48			.21				1.02	3.61	
401CF	Mixed	.08	.59	.51			.31				.13	2.20	
401CG	Larrea-Franseria		.29								.68	2.50	
401CH	Larrea-Franseria	.13	.29	.14							2.03	1.20	
BCA	Grayia-Lycium			.57				X				.31	
BCB	Grayia-Lycium	.09		.23			.11					.31	
BCC	Grayia-Lycium	.09	.08	.23								.16	
BCD	Grayia-Lycium	.09	.30	.19				X			.11		
BCE	Grayia-Lycium		.35	1.13			.11						
BCF	Grayia-Lycium	.09					.06						
CCB	Larrea-Franseria	.16	1.44	.14			.23				.23	.19	
CCC	Larrea-Franseria		.47	.14		X	.18	X			1.46		
ECD	Pinyon-Juniper							X	.41	.38			
ECE	Pinyon-Juniper								.21		.13		.14
ECF	Coleogyne								.52		.13		
FCB	Larrea-Franseria	.16	.09				.07					.39	
FCC	Larrea-Franseria	.08	.28									.48	
FCF	Coleogyne			.90								.47	
FCG	Coleogyne		.63	.10									
FCH	Coleogyne	.05	.75	.41			.06						
FCI	Coleogyne						.06				.63		
FCJ	Coleogyne		.13			X	.29						
JCD	Mixed	.08	1.42								2.17	.20	
JCE	Mixed	.17	.12	.64			.14				.50	.60	
NCA	Larrea-Franseria	.08		.28				X			1.10	.10	
TCC	Coleogyne		.63				.11		.21			.02	
TCD	Coleogyne	.05	.42				.11		.21			1.57	
TCE	Coleogyne		.28	.68			.06		.21			1.10	
TCF	Coleogyne		.56	.45								.78	
TCG	Coleogyne			1.80			.17					.31	.15
TCH	Coleogyne	.09	.38	.93			.06	X			.25		
TCI	Coleogyne	.07	.14	1.62								.31	
TCJ	Mixed			.77			.17	X			.13	.63	
TCK	Mixed	.14	.07	.45			.06				.13	.16	

[a]Acres were used in preference to ares because they provided larger units of measurement.

[b]Amm leu - *Ammospermophilus leucurus*, Dip mer - *Dipodomys merriami*, Dip mie - *Dipodomys microps*, Dip ord - *Dipodomys ordii*, Neo lep - *Neotoma lepida*, Ony tor - *Onychomys torridus*, Per cri - *Peromyscus crinitus*, Per man - *Peromyscus maniculatus*, Per tru - *Peromyscus truei*, Prg for - *Perognathus formosus*, Prg lon - *Perognathus longimembris*, Prg par - *Perognathus parvus*.

[c]These species were collected too infrequently in the grids to compute home range; thus, their densities could not be determined.

[d]See Allred, Beck and Jorgensen (1963b) for location of each study.

Dipodomys microps tends to decrease as *Eurotia lanata* decreases, and *Larrea divaricata* and *Franseria dumosa* increase (Fig. 37).

Onychomys torridus appears to decrease as *Larrea divaricata, Atriplex confertifolia,* and *Eurotia lanata* decrease; and *Grayia spinosa* and *Sitanion hansenii* increase (Fig. 38).

Perognathus formosus seems to decrease with a decrease in *Coleogyne ramosissima* and an increase in *Ephedra nevadensis* and *Oryzopsis hymenoides* (Fig. 39).

Perognathus longimembris appears to decrease with a decrease in *Lycium andersonii, Atriplex cenfertifolia, Eurotia lanata,* and *Oryzopsis hymenoides* and an increase in *Larrea divaricata* (Fig. 40).

It is apparent that the interactions of these small mammal species with the vegetation in the biotic community can only be alluded to in the absence of quantitative data on the vegetation. Also, perhaps more samples would be needed in fewer more carefully selected sites in which distributional interrelationships between major biotic communities could be established.

Seasonal Distribution

Seasonal distribution was discussed by Allred, Beck and Jorgensen (1963a). Their data were presented as "butterfly" graphs and represented relative estimates of abundance based on trap nights. Both relative densities and the trap night index can lead to rather misleading conclusions if factors such as response to traps and activity are not considered, and neither procedure is designed to consider these variables. Absolute numbers were computed in this study to reduce the possibility of erroneous conclusions.

The results of our analyses are presented in Figures 41-48. These figures do not include all of the species collected, for some were not collected in sufficient quantity to allow estimates of their densities. Each species will be briefly

Table 18. Correlation coefficients for contrasting species of small mammals among the distribution transects.

Species	Species[a]					
	Amm leu	Dip mer	Dip mic	Ony tor	Prg for	Prg lon
Ammospermophilus leucurus		.0247	.3993**	.0985	.1135	.3311**
Dipodomys merriami			-.0370	.1687	.1766	.0409
Dipodomys microps				.2251	.1588	.2741
Onychomys torridus					-.2795	.0674
Perognathus formosus						.0041

[a]Refer to left-hand species column for the abbreviated species names, except Prg lon - *Perognathus longimembris.*
**Significant at the 5% level.

Table 19. Number of transects in which the presence and absence of certain small mammal species are contrasted.

Species Present	Species Absent[a]						
Species	Amm leu	Dip mer	Dip mic	Ony tor	Prg for	Prg lon	Total Transects
Ammospermophilus leucurus		20 (29)	26 (37)	37 (53)	33 (47)	8 (11)	70
Dipodomys merriami	30 (38)		36 (45)	43 (54)	40 (50)	14 (18)	80
Dipodomys microps	19 (30)	20 (32)		31 (49)	27 (43)	9 (14)	63
Onychomys torridus	16 (31)	13 (25)	18 (35)		24 (47)	10 (19)	51
Perognathus formosus	16 (31)	12 (23)	19 (37)	26 (50)		13 (25)	52
Perognathus longimembris	29 (32)	23 (26)	36 (40)	48 (53)	50 (56)		90
Average percentage	32	27	39	52	49	17	

[a]Refer to left-hand species column for the abbreviated species names. Percentages of the transects are in parentheses.

Table 20. Summary of transects from which particular small-mammal species were collected and the percentage which included the various plant species.

Plant Species	Small-Mammal Species[a]											
	Amm leu	mer Dip	mic Dip	ord Dip	Neo lep	Ony tor	Per cri	Per man	Per tru	Prg for	Prg lon	Prg par
Acamptopappus schockleyi	8.57	3.79	7.81	0.0	11.11	9.80	0.0	0.0		3.92	6.81	
Artemisia spinescens	8.57	5.06	7.81	0.0	22.22	5.88	18.18	11.11		1.96	7.95	
Artemisia tridentata	8.57	6.32	12.50	0.0	0.0	11.76	13.63	33.33	X	9.80	6.81	X
Atriplex canescens	21.42	16.45	15.62	30.00	0.0	15.68	0.0	33.33		13.72	18.18	X
Atriplex confertifolia	44.28	29.11	37.50	10.00	33.33	29.41	45.45	11.11	X	39.21	36.36	
Bromus rubens	0.0	2.53	1.56	0.0	11.11	3.92	0.0	0.0		1.96	0.0	
Chaenactis fremontii	1.42	2.53	3.12	0.0	0.0	0.0	0.0	0.0		0.0	0.0	
Chrysothamnus viscidiflorus	4.28	5.06	6.25	0.0	11.11	9.80	9.09	0.0		9.80	3.40	
Coleogyne ramosissima	32.85	26.58	34.37	20.00	44.44	37.25	40.90	22.22		43.13	20.45	
Cowania stansburiana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.22		3.92	0.0	X
Dalea fremontii	11.42	16.45	10.93	0.0	11.11	11.76	9.09	11.11		21.56	12.51	
Dalea polyadenia	2.85	2.53	3.12	0.0	0.0	1.96	0.0	0.0		1.96	3.40	
Ephedra nevadensis	45.71	43.03	53.12	40.00	55.55	49.01	45.45	55.55		54.90	40.90	X
Ephedra funerea	1.42	2.53	3.12	0.0	0.0	1.96	0.0	0.0		3.92	2.27	
Ephedra torreyana	0.0	2.53	1.56	0.0	0.0	0.0	4.54	0.0		3.92	1.13	
Ephedra viridis	2.85	2.53	3.12	0.0	0.0	1.96	4.54	0.0		1.96	1.13	
Eriogonum fasciculatum	0.0	2.53	0.0	0.0	11.11	5.88	0.0	0.0		1.96	0.0	
Eriogonium pussellum	2.85	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.96	0.0	
Erodium cicutarium	0.0	1.26	0.0	0.0	0.0	0.0	0.0	11.11		1.96	0.0	
Eurotia lanata	41.42	37.97	40.62	50.00	33.33	39.21	27.27	22.22	X	25.49	43.18	
Franseria dumosa	32.85	35.44	21.87	0.0	0.0	13.72	9.09	0.0		39.21	32.95	
Grayia spinosa	42.85	37.97	39.06	30.00	33.33	39.21	40.90	0.0		37.25	42.04	
Haplopappus cooperi	14.28	16.45	12.50	10.00	11.11	15.68	9.09	11.11		13.72	17.04	
Hymenoclea salsola	8.75	13.92	9.37	20.00	22.22	15.68	0.0	11.11		9.80	12.50	
Juniperus osteosperma	0.0	0.0	0.0	0.0	0.0	0.0	4.54	22.22	X	1.96	0.0	X

Kochia americana	0.0	1.26	1.56	0.0	0.0	0.0	0.0	11.11		0.0	2.27	
Krameria parvifolia	20.00	25.31	18.75	0.0	11.11	11.76	22.72	11.11		33.33	21.59	
Larrea divaricata	42.85	43.03	32.81	0.0	11.11	13.72	27.27	0.0		50.98	39.77	
Lepidium fremontii	0.0	0.0	1.56	0.0	0.0	0.0	4.54	0.0		0.0	1.13	
Lycium andersonii	44.28	40.50	42.18	30.00	44.44	43.13	40.90	22.22		45.09	42.04	
Lycium pallidum	17.14	24.05	14.06	0.0	0.0	11.76	4.54	0.0		21.56	19.31	
Lycium rickardii	2.85	6.32	3.12	0.0	0.0	1.96	4.54	0.0		5.88	3.40	
Menodora spinescens	8.57	10.12	6.25	0.0	11.11	9.80	4.54	0.0		9.80	9.09	
Mentzelia albicaulis	1.42	6.32	3.12	10.00	0.0	1.96	4.54	0.0		1.96	2.27	
Mirabilis bigelovii	0.0	2.53	0.0	0.0	11.11	3.92	0.0	0.0		1.96	0.0	
Mirabilis pudica	4.28	2.53	1.56	30.00	0.0	1.96	0.0	0.0		0.0	3.40	
Oryzopsis hymenoides	24.28	24.05	20.31	30.00	11.11	17.64	13.63	22.22		17.64	26.13	X
Petalonyx sp.	0.0	1.26	0.0	0.0	11.11	5.88	4.54	0.0		1.96	0.0	
Phacelia fremontii	1.42	1.26	1.56	0.0	0.0	0.0	4.54	0.0		1.96	0.0	
Pinus monophylla	0.0	1.26	1.56	0.0	0.0	1.96	4.54	11.11	X	1.96	0.0	X
Purshia tridentata	0.0	1.26	0.0	0.0	11.11	3.92	0.0	11.11		1.96	0.0	
Salazaria mexicana	2.85	3.79	3.12	0.0	11.11	5.88	0.0	0.0		3.92	2.27	
Salsola kali	11.42	7.59	9.37	20.00	11.11	5.88	4.54	11.11		0.0	9.09	
Sitanion hansenii	10.00	8.86	15.62	20.00	0.0	17.64	13.63	0.0		7.84	9.09	
Stanleya pinnata	2.85	2.53	4.68	0.0	11.11	5.88	4.54	11.11		1.96	2.27	
Stipa comata	0.0	2.53	0.0	0.0	11.11	5.88	0.0	0.0		3.92	6.81	
Stipa speciosa	2.85	5.06	3.12	10.00	11.11	9.80	4.54	11.11		3.92	6.81	
Syntrichopappus fremontii	0.0	1.26	1.56	0.0	0.0	1.96	4.54	0.0		1.96	0.0	
Tetradymia glabrata	12.85	7.59	17.18	40.00	11.11	17.64	13.63	11.11		7.84	12.50	
Tetradymia axillaris	4.28	6.32	6.25	10.00	0.0	9.80	4.54	0.0		5.88	5.68	
Thamnosma montana	1.42	2.53	3.12	0.0	11.11	3.92	4.54	0.0		3.92	1.13	
Yucca brevifolia	12.85	13.92	14.06	20.00	22.22	7.84	36.36	22.22		21.56	9.09	
Yucca schidigera	1.42	3.79	3.12	0.0	0.0	1.96	0.0	0.0		5.88	2.27	

[a]Amm leu - *Ammospermophilus leucurus*, Dip mer - *Dipodomys merriami*, Dip mie - *Dipodomys microps*, Dip ord - *Dipodomys ordii*, Neo lep - *Neotoma lepida*, Ony tor - *Onychomys torridus*, Per cri - *Peromyscus crinitus*, Per man - *Peromyscus maniculatus*, Per tru - *Peromyscus truei*, Prg for - *Perognathus formosus*, Prg lon - *Perognathus longimembris*, Prg par - *Perognathus parvus*.

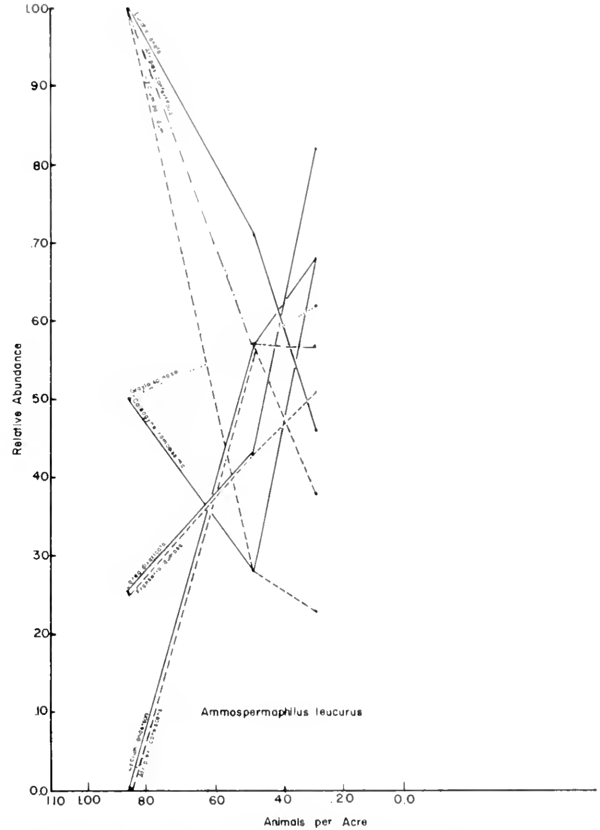


Figure 35. Vegetation as related to decreased density of *Ammospermophilus leucurus*. The points on the graph are situated at the mean number of animals per acre for that density category.

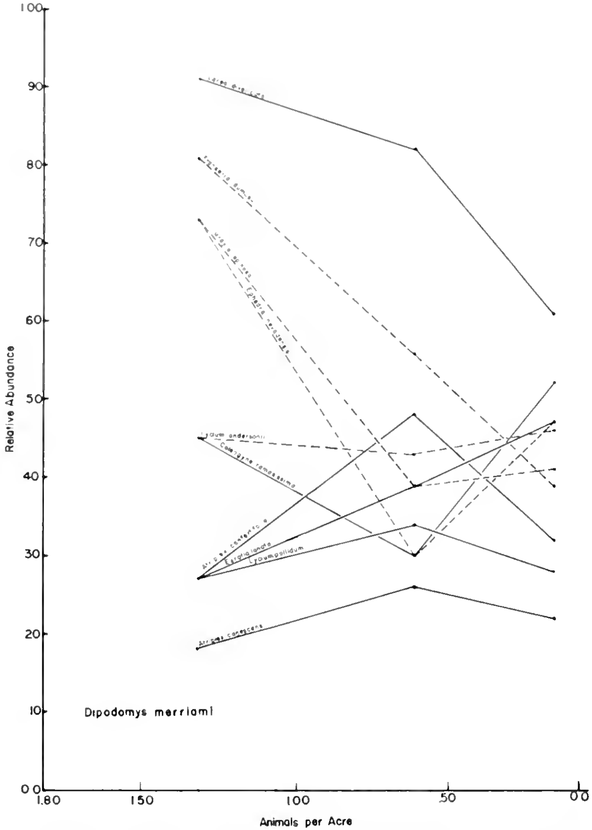


Figure 36. Vegetation as related to decreased density of *Dipodomys merriami*. Points on the graph are situated at the mean number of animals per acre for that density category.

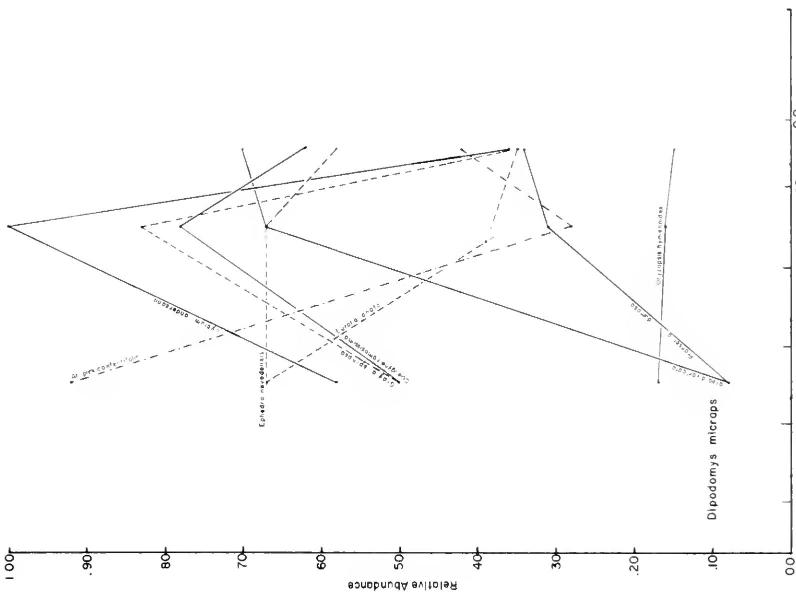


Figure 37. Vegetation as related to decreased density of *Dipodomys microps*. The points on the graph are situated at the mean number of animals per acre for that density category.

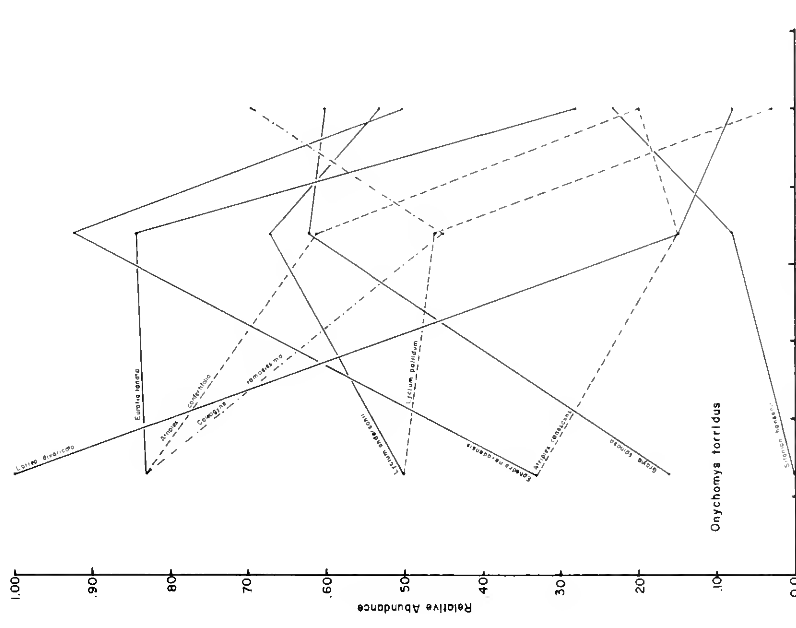


Figure 38. Vegetation as related to decreased density of *Onychomys torridus*. The points on the graph are situated at the mean number of animals per acre for that density category.

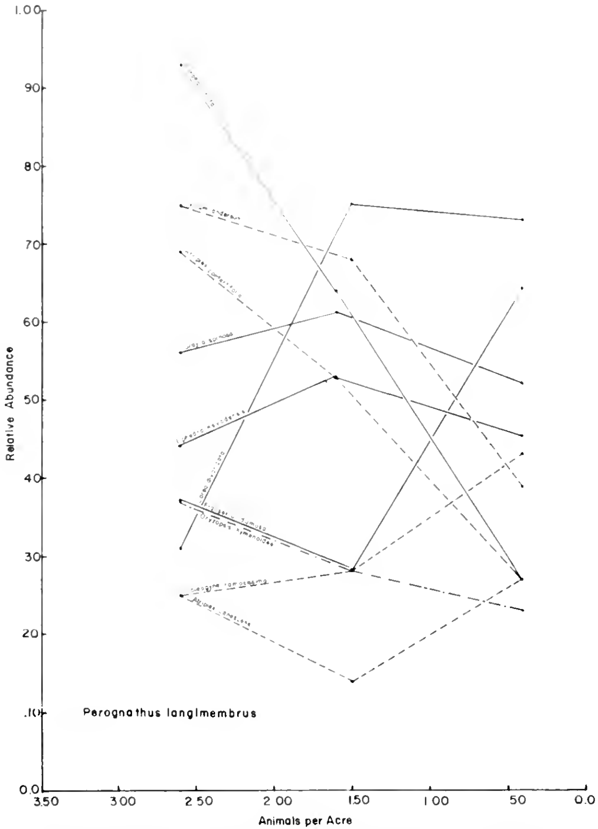


Figure 40. Vegetation as related to decreased density of *Perognathus longimembris*. The points on the graph are situated at the mean number of animals per acre for that density category.

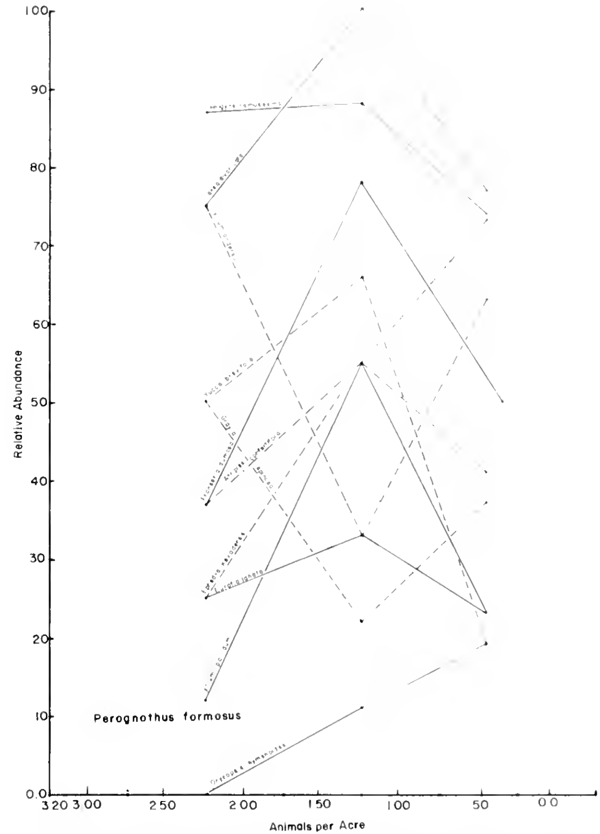


Figure 39. Vegetation as related to decreased density of *Perognathus formosus*. The points on the graph are situated at the mean number of animals per acre for that density category.

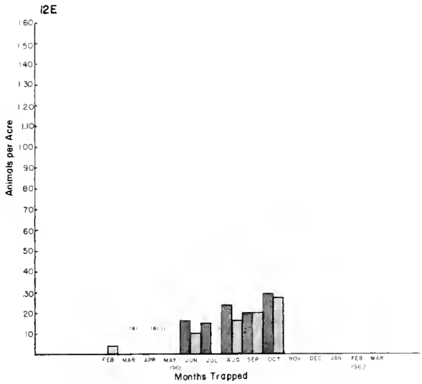


Figure 41. Seasonal distribution of *Peromyscus truei;* 12E - undisturbed Pinyon-Juniper. Numbers in parentheses represent those captured with no recaptures. Males—linear bars; Females—stippled bars.

summarized to facilitate a better evaluation of these data.

Peromyscus truei (Fig. 41) was collected abundantly only from Pinyon-Juniper communities and then primarily from the grid which had not been disturbed by nuclear weapons testing. This grid (12E) was discontinued October, 1961 because of inclement conditions and not resumed until April, 1962. The lack of sampling accounts for the sudden drop.

Peromyscus maniculatus (Fig. 42) was collected in small numbers in all of the grids, but was abundant only in the Pinyon-Juniper. Both of the grids placed in Pinyon-Juniper were discontinued in October, 1961 because of inclement conditions. The differences in densities between April, 1962 and April, 1961 are rather striking in each grid. The wide fluctuations are not easily explained, but could be due in part to extended home ranges of females during the supposed lactating period.

Perognathus formosus (Fig. 43) was not collected during the winter months because of its inactivity. It became active during the early spring and generally remained active through October. Occasionally, a few individuals were trapped during the winter, but no explanation for this activity is available. During the summer of 1961 they were rather abundant in JA (Larrea-Franseria), but essentially absent from 5E (Larrea-Franseria). Also in 5E there appear to have been more individuals active during the harsh winter months. Perhaps the small population build-up during the 1961 season was due to the winter mortality during the preceding winter.

Perognathus longimembris (Fig. 44) has a seasonal distribution similar to that of *P. formosus,* being active essentially from March through September. They were captured only sporadically during the winter.

Striking differences in numbers frequently appeared between successive years. During 1961 the population which had been present the previous year in 5E had dropped considerably. No explanation is readily available for this type of yearly decline.

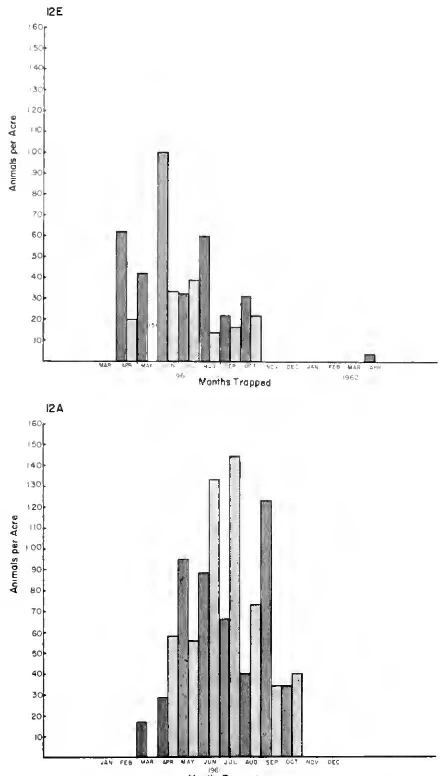


Figure 42. Seasonal distribution of *Peromyscus maniculatus;* 12E - undisturbed Pinyon-Juniper, 12A - disturbed Pinyon-Juniper. Numbers in parentheses represent those captured with no recaptures. Males—linear bars; Females—stippled bars.

Dipodomys ordii (Fig. 45) was collected abundantly from only one grid (1F), and it was in a Salsola community. The high density during the spring of 1961 gradually decreased until November, when very few animals were present. Subsequent trappings in this area indicated that they have never yet returned in substantial numbers. It is evident that this reaction is a response to the *Salsola kali* which invaded the area shortly after the last nuclear weapons test (Shields and Wells, 1960). As growing conditions become less suitable for Russian thistle, and since no other vegetation has replaced it, the area was once again almost void of vegetation. As the food supply in the summer of 1961 dwindled, so did *D. ordii* until in the winter it appeared that there was not sufficient food or cover to maintain them.

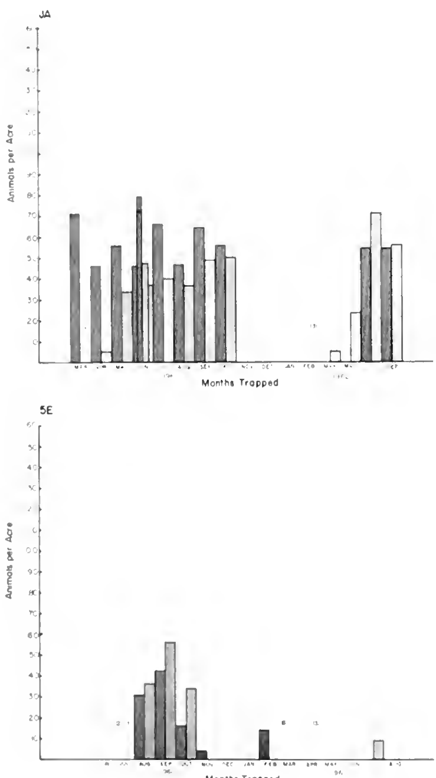


Figure 43. Seasonal distribution of *Perognathus formosus;* JA - mixed Larrea-Franseria, 5E - *Lycium pallidum* association of Larrea-Franseria. Numbers in parentheses represent those captured with no recaptures. Males—linear bars; Females—stippled bars.

Dipodomys merriami (Fig. 46) fluctuated considerably throughout the year, but was generally most abundant in the spring and summer months. The rather significant decrease in 1F during the spring of 1961 resulted essentially from the death of adults and sub-adults presumably unable to survive the winter months. This decline resulted in their elimination, which has persisted since and probably resulted from the lack of food when *Salsola kali* failed to return. The highest populations were evidently during the spring months when the largest numbers of young were present.

Dipodomys microps (Fig. 47) had seasonal distributions which were generally similar to those of *D. merriami* except that the largest population generally was somewhat later in the spring and early summer. Also, the decline during the winter months was usually more abrupt, sometimes resulting in practically no captures. This probably does not stem from hibernation behavior, for on trapping days which were favorable, large numbers were frequently trapped (e.g. 10D; January, 1961). It seems more likely to result from foraging behavior.

Trapping results of *Ammospermophilus leucurus* (Fig. 48) were extremely sporadic. This probably resulted from their large activity ranges and the fact that the grids were generally too small to include their movement. Also, since the traps were serviced during the early morning only and *A. leucurus* is active during the day, many were found dead in the traps. Data for this species must be carefully evaluated, because the two behavior characteristics described would influence the trapping results considerably.

Some general comments concerning these data may also be made. It is easily seen that rather large fluctuations in small mammal densities are evident from one month to the next. Also, rather large differences appear between the densities of males and females. On the surface those differences might be interpreted to represent real changes in the population densities. This conclusion need not necessarily be eliminated, but care must be exercised to avoid interpreting behavioral influence in the computation techniques as real changes in size of the population.

If individuals or classes of individuals (e.g. females or sub-adults) have a large home range, the probability of contacting a trap is increased and they will appear in traps more frequently than individuals or classes of individuals with

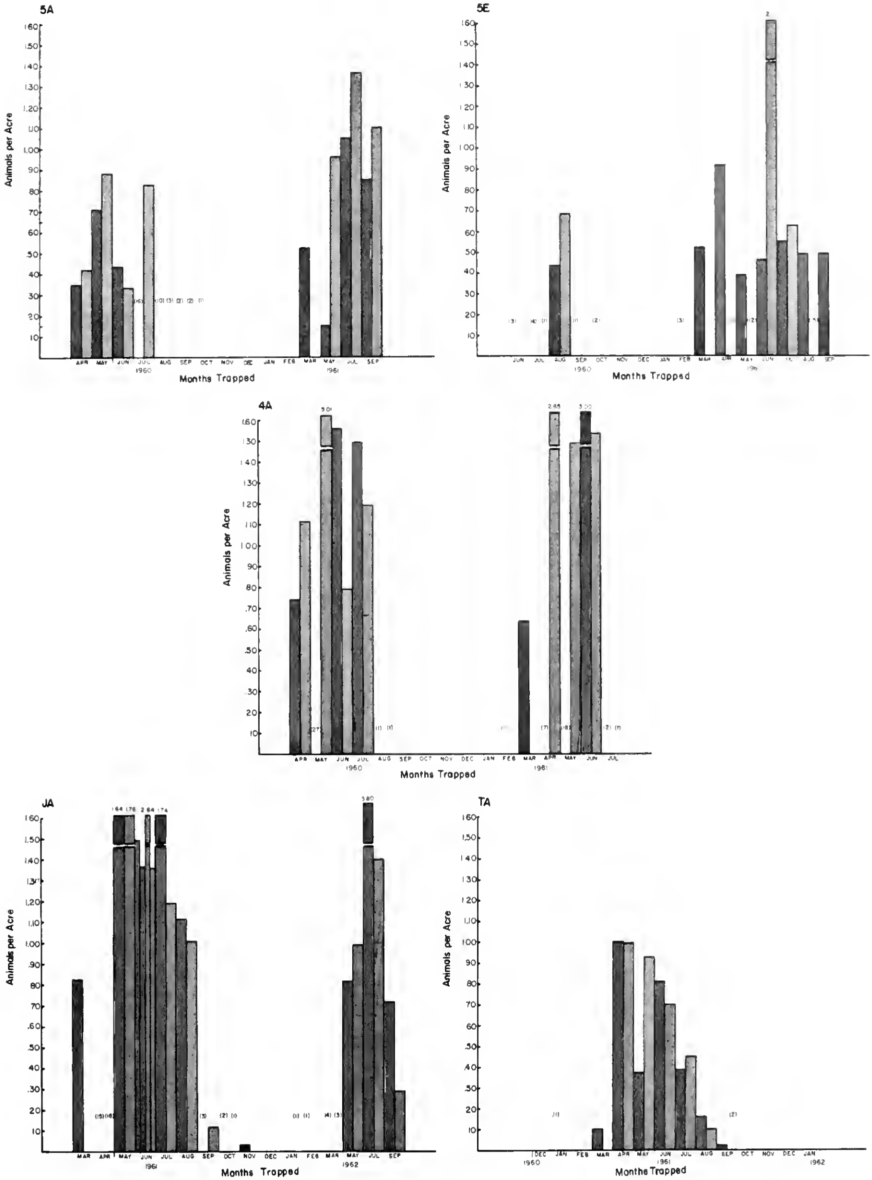


Figure 44. Seasonal distribution of *Perognathus longimembris;* 5A - Larrea-Franseria, 5E - *Lycium pallidum* association of Larrea-Franseria, 4A - Grayia-Lycium, JA - mixed Larrea-Franseria, TA - *Artemisia tridentata* association in Coleogyne. Numbers in parentheses represent those captured with no recaptures. Males—linear bars; Females—stippled bars.

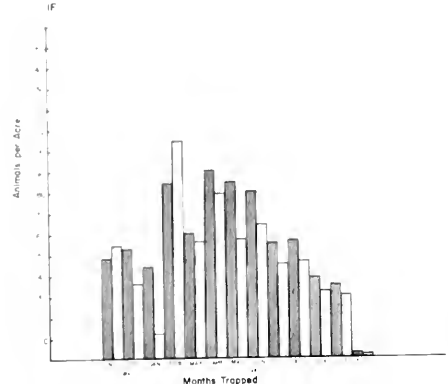


Figure 45. Seasonal distribution of *Dipodomys ordii;* 1F - Salsola. Males—linear bars; Females—stippled bars.

smaller home ranges. The results of these data may be interpreted erroneously as larger numbers if care is not taken to consider the size of the home range. Foraging behavior, sexual activity, population age structure, and other factors may have similar influences and should be considered whenever possible.

Discussion of Species Distribution

If one were to understand the spatial distribution of even a single species, it would necessitate an exhaustive study (Jorgensen, 1963). Sampling and analyses as extensive as this were not possible in this study; consequently only trends or general observations are possible.

Allred, Beck and Jorgensen (1963a) indicated that *A. leucurus* is more abundant in the Larrea-Franseria community than all other communities sampled. Two of the plant species

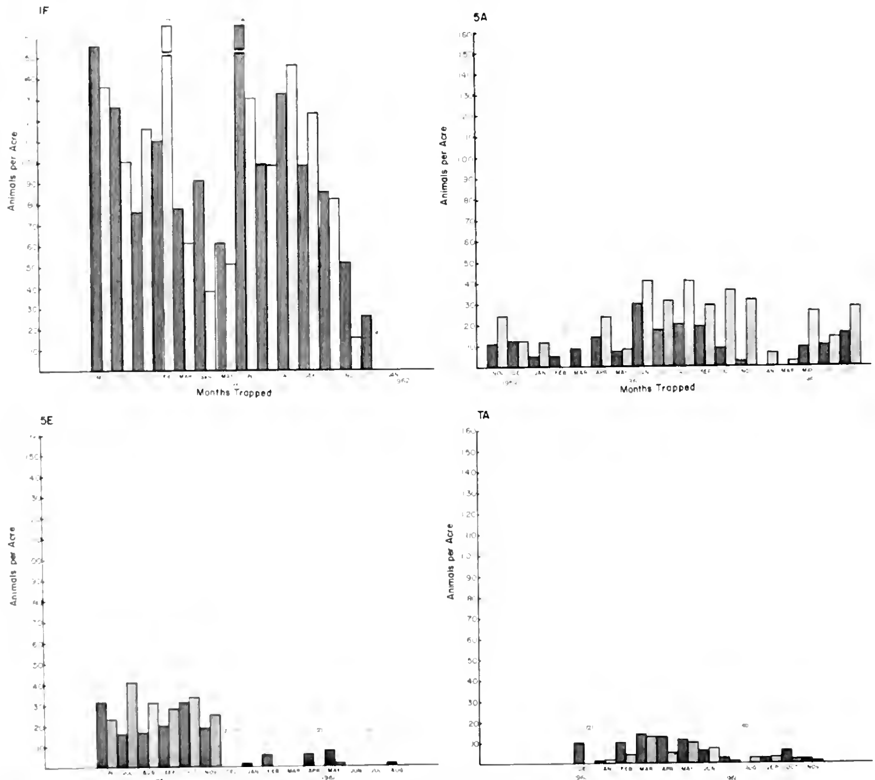


Figure 46. Seasonal distribution of *Dipodomys merriami;* 1F - Salsola, 5A - Larrea-Franseria, 5E - *Lycium pallidum* association of Larrea-Franseria, TA - *Artemisia tridentata* association in Coleogyne. Numbers in parentheses represent those captured with no recaptures. Males—linear bars; Females—stippled bars.

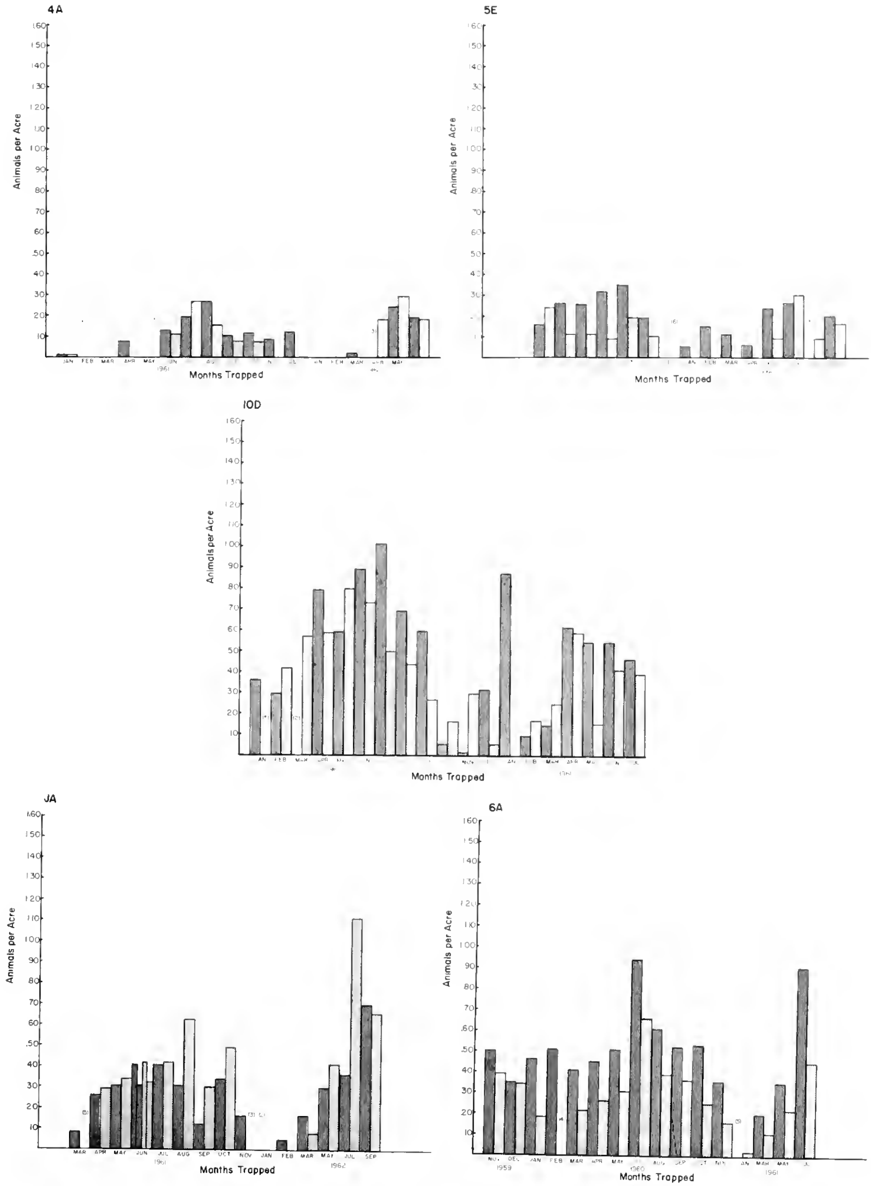
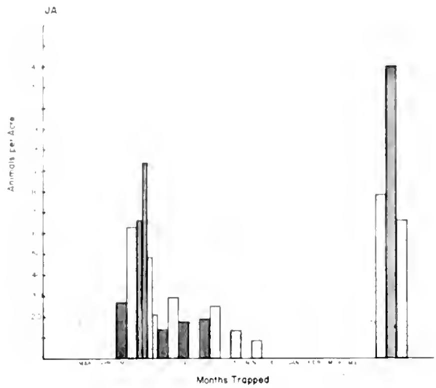


Figure 47. Seasonal distribution of *Dipodomys microps;* 4A - Grayia-Lycium, 5E - *Lycium pallidum* association of Larrea-Franseria, 10D - Coleogyne, JA - mixed Larrea-Franseria, 6A - Atriplex-Kochia. Numbers in parentheses represent those captured with no recaptures. Males—linear bars; Females—stippled bars.



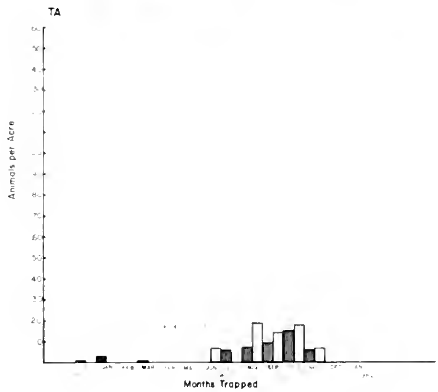


Figure 48. Seasonal distribution of *Ammospermophilus leucurus;* JA - mixed Larrea-Franseria, TA - *Artemisia tridentata* association of Coleogyne. Numbers in parentheses represent those captured with no recaptures. Males—linear bars; Females—stippled bars.

which characterize Larrea-Franseria are *Larrea divaricata* and *Franseria dumosa* (Table 10). Both of these species increased as the density of *A. leucurus* decreased (Fig. 35), contrary to the findings of Allred, Beck and Jorgensen (1963a). Actually the density of ground squirrels in what is considered typical Larrea-Franseria is rather low, but other plant associations assigned to Larrea-Franseria and marginal areas maintain larger populations. For this reason pooling all of them together in one relative estimate would lead to erroneous conclusions as to the influence *Larrea divaricata* and *Franseria dumosa* have on the distribution of *A. leucurus*. However, when the other plant species are taken into consideration, it is apparent that *A. leucurus* is most abundant in the marginal areas where *Eurotia lanata*, *Atriplex confertifolia*, and *Lycium pallidum* are important constituents of the flora.

This also accounts for the large numbers collected in Grayia-Lycium and suggests that Grayia-Lycium and perhaps Coleogyne are merely extensive ecotones themselves. In this sense they would represent an ecotone system between the Larrea-Franseria, and the Artemisia communities north of the test site.

The results of our studies (Fig. 36) agree generally with those of Allred, Beck and Jorgensen (1963a), indicating that *D. merriami* is most abundant in the Larrea-Franseria community. In this case it is apparent that this species is a warm desert species centering its distribution around typical Larrea-Franseria and partially avoiding the marginal areas.

An *Artemisia tridentata* association of the Coleogyne community in Mid-Valley was found to have more *D. merriami* than any other kangaroo rat. Since *D. microps* was the predominant species in *Artemisia tridentata* north of the test site in Kawich Valley, it seemed rather unusual to find *D. merriami* in the sagebrush at the test site. Sharp boundaries between *Coleogyne* and *Artemisia* were accompanied by an equally sharp change in kangaroo rat species. Within very few feet the composition changed from predominantly *D. microps* to predominantly *D. merriami* as vegetation changed from *Coleogyne* to *Artemisia*. Table 12 indicated that the home range is larger in the *Artemisia* (TA) than any other community, and this could account, in part, for the apparent abundance of *D. merriami*.

Dipodomys microps was reported as being most abundant in Coleogyne and Atriplex-Kochia by Allred, Beck and Jorgensen (1963a). These results agree with our data when the predominant plant species are considered in each of these communities. *Eurotia lanata* and *Atriplex confertifolia* seem to be correlated with the distribution of *D. microps*. Since these are marginal plant species in this area, it suggests that *D. microps* readily inhabits the marginal or ecotone areas between the Mohave and Great Basin vegetation.

Although there is some indication that certain plant species may influence the distribution of *O. torridus*, there is no clear correlation between its distribution and that of the plants. Generally, it appears that this species is present in almost all communities, though not abundantly.

According to Allred, Beck and Jorgensen (1963a) *P. formosus* is most abundant in Larrea-Franseria. Although *Larrea divaricata* and *Franseria dumosa* seemed to have no particular ef-

fect on the distribution of *P. formosus* in our analyses, densities of the pocket mouse did decrease as the abundance of *Coleogyne ramosissima* decreased (Fig. 39). The distribution of this pocket mouse seemed to be influenced more by the soil texture than by plant species, except that they were virtually absent from areas with very little shrub cover. They were observed to be most commonly collected from the less stable soils with exposed gravel, and along washes. Since these edaphic conditions are most frequently found in the marginal ecotone areas, *P. formosus* apparently prefers these areas. Therefore, although they are not abundant in typical Larrea-Franseria, they are frequently collected from the marginal areas around and within it.

Perognathus longimembris was reported by Allred, Beck and Jorgensen (1963a) to be more abundant in Larrea-Franseria than any other community. *Larrea divaricata* is one of the characteristic species in this community, and it decreased as the density of small mammals increased (Fig. 40). The distribution of this species was much like that of *P. formosus* in that it was less abundant in the typical Larrea-Franseria than it was in the marginal areas. The primary difference was that *P. longimembris* preferred the sandy unstable soils of the lower bajada, whereas *P. formosus* seemed to prefer the soils which were more rocky. Although it is not conclusively shown, one is impressed with the possibility that both *P. formosus* and *P. longimembris* are influenced more by the condition of the soil and availability of cover than by the vegetation composition.

DISCUSSION AND CONCLUSIONS

The data presented and discussed throughout this report were intended to furnish a basic understanding of three problems: what small mammals are present at the Nevada Test Site, where they are, and when they are active. Some data concerning these problems were presented by Allred, Beck and Jorgensen (1963a), but their work was preliminary and provided little quantitative data. Our data should provide a more complete basis for any future work on mammals at the test site. The three primary objectives will be considered under separate headings in this section.

Mammal Species at the Nevada Test Site

Forty-six species have been collected or observed by us at the test site. Hall (1946) indicated with his distribution maps that the following eight additional species also had ranges which included the test site area: *Myotis yumanensis yumanensis* (H. Allen), Yuma Myotis; *Myotis californicus pallidus* (Stephens), California Myotis; *Myotis subulatus melanorhinus* (Merriam), Small-footed Myotis; *Lasionycteris noctivagans* (LeConte), Silvery-haired Bat; *Eptesicus fuscus pallidus* Young, Big brown Bat; *Tadarida mexicana* (Saussure), Mexican Free-tailed Bat; *Mephitis mephitis major* (Howell), Striped Skunk; and *Urocyon cinereoargenteus scotti* (Mearns) Gray Fox. It is likely that these species will eventually be collected at the test site, but in any case they would have to be considered rare. Perhaps more of the bats would have been recorded had there been a more concerted effort made to collect them.

Even the most cursory observation of the Nevada Test Site mammals shows the influence of the Mohave desert and Great Basin desert on the fauna. Species typical of the hot Mohave desert, such as *Spermophilus tereticaudus*, *Dipodomys merriami*, *Onychomys torridus*, and *Peromyscus eremicus* were represented along with species typical of the cooler Great Basin desert, such as *Spermophilus townsendii*, *Perognathus parvus*, *Dipodomys ordii*, *Dipodomys microps*, *Lagurus curtatus*, and *Sylvilagus nuttallii*. Still others were collected which seemed to disregard the somewhat hazy ecotone between these two deserts. The geographic position of the test site, being situated on this ecotone, provided an opportunity to examine the overlapping of many species. In Frenchman Flat *D. merriami*, *D. microps*, and *D. deserti* inhabited the same area, while *P. eremicus*, *P. crinitus*, and *P. maniculatus* occupied another area together. *Dipodomys microps*, *D. merriami*, *D. ordii*, and *D. deserti* all occupied an area in Yucca Flat which had been disturbed by nuclear weapons testing. The presence of Mohave desert and Great Basin desert mammal faunas along with the wide overlapping of distributional ranges verifies further the ecotonal situation of the Nevada Test Site. Since mammals at the test site are living at the margins of their typical habitats, experimental work must be interpreted with care before the results are applied to areas farther north and south.

Spatial Distribution of Mammals at the Nevada Test Site

Perhaps one of the most difficult problems in understanding mammals in an ecotone area is their distribution among the many different habitats. Some plant species occupy several niches, possibly imposing different influences on the mammal distribution. Mammal species may find the area they occupy crowded with other species which they do not ordinarily encounter in the more typical parts of their range. These and many other factors must be interpreted if an understanding of mammal distribution is to be complete. Although we have by no means all the answers, our data are helpful in solving a few of the problems. Most of our results are related to small mammals, and only these data are considered in detail.

Two primary aspects of small mammal distribution are particularly evident: the occurence of species in relation to elevation changes and the changing fauna as the ecotone is transected between the Mohave desert and the Great Basin desert. Although many of the same plant and small mammal species are present in both aspects, their relative compositions are frequently different. The functional niches occupied by the small mammals are of particular interest but only in the sense that they allow a better understanding of the relationships among the biotic communities.

The aspect of changing elevations is repeated many times in the numerous valleys found within the southwestern deserts. Changes in elevation are frequently accompanied by rather striking differences in vegetation as well as small mammal composition. Variations are also evident as adaptations to smaller and different edaphic conditions. In valleys at the test site where Larrea-Franseria occupies the valley floor, there are usually two vegetation zones more or less developed as one moves up the bajada onto the foothills. These two are the Lycium association of Larrea-Franseria and Coleogyne.

If a transect were sampled across the ecotone between the Mohave desert and the Great Basin desert, several valleys would likely be crossed. These valleys frequently have different elevations, latitudes, and drainage systems which combine to make up different biotic habitats in each valley. Because of the differences among these valleys, any one species may occupy several functional or spatial niches. Examples of this are *Grayia spinosa* and *Lycium andersonii*, which are identified with a distinct biotic community in Yucca Flat, but are scattered among communities typified by other species in Frenchman Flat. *Larrea divaricata* is a prominent feature of the most extensive biotic community in Frenchman Flat, but is relegated to local areas which apparently trap the warm air in Yucca Flat. Generally, as one moves from the north to the south at the test site, one descends in elevation. This is the condition under which the ecotone has developed between the Mohave and Great Basin deserts at the test site. From the north to the south this ecotone is characterized by communities of Coleogyne and Grayia-Lycium with their respective plant associations. Note that these are similar to the communities observed in ascending from the valley floors onto the surrounding foothills as described previously.

If the small mammal species in the two similar biotic communities (Coleogyne, and Grayia-Lycium and Lycium association of Larrea-Franseria) are examined, it is evident that the species composition is also similar even though their respective densities may be different. In this sense, pooling small mammal samples from Coleogyne or Lycium and Grayia-Lycium cannot be justified and should not be done if the communities occur under different conditions. For example, samples taken from Coleogyne when it forms a community in the ecotone between the Mohave and the Great Basin deserts should not be pooled with samples taken from Coleogyne when it occurs as a community surrounding the upper elevations of some particular valley whose floor is occupied with Larrea-Franseria. Data concerning a small mammal species in one Coleogyne community are comparable to data from another only if the two communities occupy comparable stages relative to the succession of vegetation. If this is true between two communities which are faunistically and floristically similar, it is even more so between very different communities such as Coleogyne and Larrea-Franseria. These differences are thought to be responsible for some of the rather striking discrepancies found while studying the same small mammal species in the various biotic communities at the test site.

With these concepts and limitations in mind, the spatial distribution of small mammals may be considered, although *Dipodomys* and *Perognathus* are the only genera for which we have sufficient data to be particularly meaningful. Both of these genera react to the changing biotic communities within the ecotone between the Mohave and Great Basin deserts by gradually changing species composition and relative numbers. There is a general change from *D. microps* and *D. ordii* in the Artemisia north of the

test site to *D. merriami* in the Larrea-Franseria. The Coleogyne contained essentially *D. microps* while the Gravia-Lycium contained both *D. microps* and *D. merriami*. *Dipodomys* seemed to respond to changes in the various plant associations within the principal biotic communities, sometimes resulting in rather striking differences evident within only a few feet.

The species composition of *Perognathus* changed very little among the biotic communities between the Mohave desert and the Great Basin desert. The only change within the ecotone between the two deserts was a change from *P. parvus* in the Artemisia and Pinyon-Juniper to *P. formosus* and *P. longimembris* as the Mohave desert was approached. Both *P. formosus* and *P. longimembris* were most abundant in the marginal areas of Larrea-Franseria and on the upper bajada in valleys covered with Larrea-Franseria.

If the data resulting in these conclusions are interpreted correctly, the species of *Perognathus* and *Dipodomys* could be used as indicators of certain biotic communities. *Dipodomys* may be used to interpret the ecotone between the Great Basin desert and Mohave desert, and *Perognathus* may be used to interpret the physiognomy within the valleys resulting from habitat changes. The effects of nuclear weapons testing on small mammals might be much better understood when extrapolation techniques are necessary if the above-mentioned relationships are kept in mind.

Seasonal Activity of Small Mammals at the Nevada Test Site

Seasonal activity was shown to vary with several aspects of mammal behavior. In each case the answer as to when the mammals were present or active depended entirely on how they responded to the traps. Not only do traps have some influence on the assessment of their activity, but they may have different effects at different times of the year. This seems to be particularly true in cases where the activity radii from the apparent center of activity change with seasonal behavior adjustments. Many of these limiting factors could not be accurately evaluated in this report although some were recognized and the need for further study was rather obvious, particularly if experimental work is to be conducted on these populations of desert small mammal species.

With the exception of *Perognathus*, which hibernated from early fall to early spring, most of the species were active and could be trapped throughout the year. The extent to which small mammals were at risk of being trapped varied considerably, however, since it was dependant on such factors as activity range, foraging behavior, and density. Any increase in density is usually evident since it is easily observed by repeated trapping and may be shown by plotting computed numbers of individuals on the graph. Also, immigrants into a population are easily observed by recording the individuals new to the sampling area.

There were instances, however, where the immigrants and new animals could not possibly account for the sudden increase in the estimated number. In some instances the extended activity radii were plausible reasons for the apparent increase while at other times it seemed as though additional behavioral characteristics were responsible. Further work is necessary before the influence of these factors on estimated numbers can be positively determined.

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SCORPIONS OF THE NEVADA TEST SITE

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and
Dorald M. Allred

Biological Series — Volume VI, No. 4

March 1965

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FOREWORD

This is another of a series of major publications on desert ecology resulting from studies at the Nevada Test Site by the Brigham Young University Department of Zoology and Entomology in cooperation with the United States Atomic Energy Commission. Although some of the studies are the result of independent investigations by specialists who are not on our departmental staff, they are part of the major project initiated cooperatively by B.Y.U. and the A.E.C. to determine the effect of nuclear detonations on the native animals of the Nevada Test Site.

Dorald M. Allred
and
D Elden Beck

Project Supervisors

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SCORPIONS OF THE NEVADA TEST SITE[1]

By

Willis J. Gertsch[2] and Dorald M. Allred[3]

INTRODUCTION

The distinctive body form of the scorpions distinguishes them as well-known land arachnids familiar to most peoples in temperate and tropical regions. In front large chelate pedipalps with grasping fingers reach out to seize and hold insects and other small ground animals making up their prey. The greatly elongated postabdomen, or tail, which is looped forward over the body to strike in front of the head or to the side, bears a sharp terminal sting used to inject venom into their victims. The venoms of some scorpions (in North America almost exclusively those of a few species of *Centruroides*) contain neurotoxic elements that cause severe or lethal systemic reactions in warm-blooded animals. In man the venoms of these species are capable of causing grave symptoms or even death, especially in children. No species of *Centruroides* is known from the Nevada Test Site although the genus has a wide range in Arizona, even into some northern counties. This absence of *Centruroides* is also conspicuous in the Mojave Desert and other desert and foothill country of southern California which would seem to offer ideal conditions for the genus.

Scorpions live in many climatic zones but have reached their highest development in warm, arid regions. They are nocturnal in habit and during the day hide under rocks or ground detritus, in burrows, or lie buried in sand. By this activity pattern they escape the heat of the day. However, desert scorpions are especially hardy types known to be able to survive the extremely hot air and ground temperatures of this habitat even better than desert insects.

Scorpions live for several years and gradually attain full size by periodic molting. During this development they modify some of their features to the confusion of the systematist. The population of any species is a somewhat heterogeneous assortment with many variables of color base and pattern, size, and proportions of segments affecting robustness, as well as sex. Mature males of the Vejovidae are typically smaller than females with more slender postabdomens and stouter pedipalpi. Very young specimens can most often be assigned to the proper sex on the basis of features of the genital operculum and orifice. Such immature scorpions are less easily placed to species because of morphological changes during growth. On the other hand, it is possible to recognize some species on the basis of characters, sometimes seemingly trivial details of color pattern, readily traced from young to adult. Almost nothing is known about the bionomics of any of our North American scorpions.

The systematics of our southwestern scorpion fauna has been largely neglected in spite of the accumulation of large collections in various depositories. The opportunity to study the present material from the Nevada Test Site was made available by Dr. D Elden Beck and his associates of Brigham Young University, to whom we proffer our sincere thanks. The responsibility of the senior author of this paper rests with the systematics, whereas that of the junior author is concerned with the bionomics and ecology.

THE SCORPION FAUNA

This paper is based on the large, representative scorpion collections made from 1959 to 1964 at the Nevada Test Site by members of Brigham Young University's Department of Zoology and Entomology. The physical appearance and biotic communities of this large expanse of arid land in southern Nevada, comprising more than a thousand square miles, were described by Allred *et al.* (1963a and 1963b). Nine species of scorpions live in the area, and

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all represent new records for Nevada since there have been to our knowledge no published records of scorpions from the state. Few areas of similar size in our southwestern region can boast of so large a representation of species. From this same area Muma (1963) reported 28 species of another group of arachnids, the Solpugida, also strongly represented in arid regions.

The scorpion family Chactidae is represented by *Superstitionia donensis* Stahnke, which occurs in the foothill country from eastern Arizona to southern California and southward into Baja California. The present records from southern Nevada are the most northern for this small species.

The remaining eight species belong to the family Vejovidae, the most notable of which are some species of the genus *Vejovis*. *Vejovis confusus* Stahnke is the most abundant scorpion at the Test Site and accounts for more than half the total specimens of the entire collection. *Vejovis hirsuticauda* Banks is an uncommon species until now known only from San Bernardino County, California, adjacent Arizona, and northern Baja California. *Vejovis boreus* Girard is a boreal species with very wide distribution, which lives at the Test Site with its near relative, *Vejovis becki*, new species.

KEY TO THE SPECIES OF SCORPIONS

1. Only two side eyes present (Family Chactidae) ... *Superstitionia donensis* Stahnke

   Three principal side eyes present (Family Vejovidae) ... 2

2. Lower margin of movable finger of chelicera with single conspicuous dark tooth (Fig. 14); genus *Hadrurus* ... 3

   Lower margin lacking single large tooth, variable, with keel smooth, crenate, lobed or pluridentate ... 4

3. Carapace all dark brown or black to front margin ... *Hadrurus spadix* Stahnke

   Carapace pale in interocular area ... *Hadrurus arizonensis* Ewing

4. Middle lamellae of pectines consisting of about five irregular pieces (Fig. 16); telson of male usually with swollen sting (Fig. 17); pedipalps heavy with black fingers ... *Anuroctonus phaeodactylus* (Wood)

   Middle lamellae consisting of six or more regular pieces (Fig. 5) ... 5

5. Hand of pedipalp essentially smooth; lower margin of movable finger usually smooth ... 6

   Hand of pedipalp with prominent, granulose keels; lower margin of movable finger usually crenulate or dentate ... 8

6. Vesicle of telson (Fig. 13) with thick brush of very long, soft hairs ... *Vejovis hirsuticauda* Banks

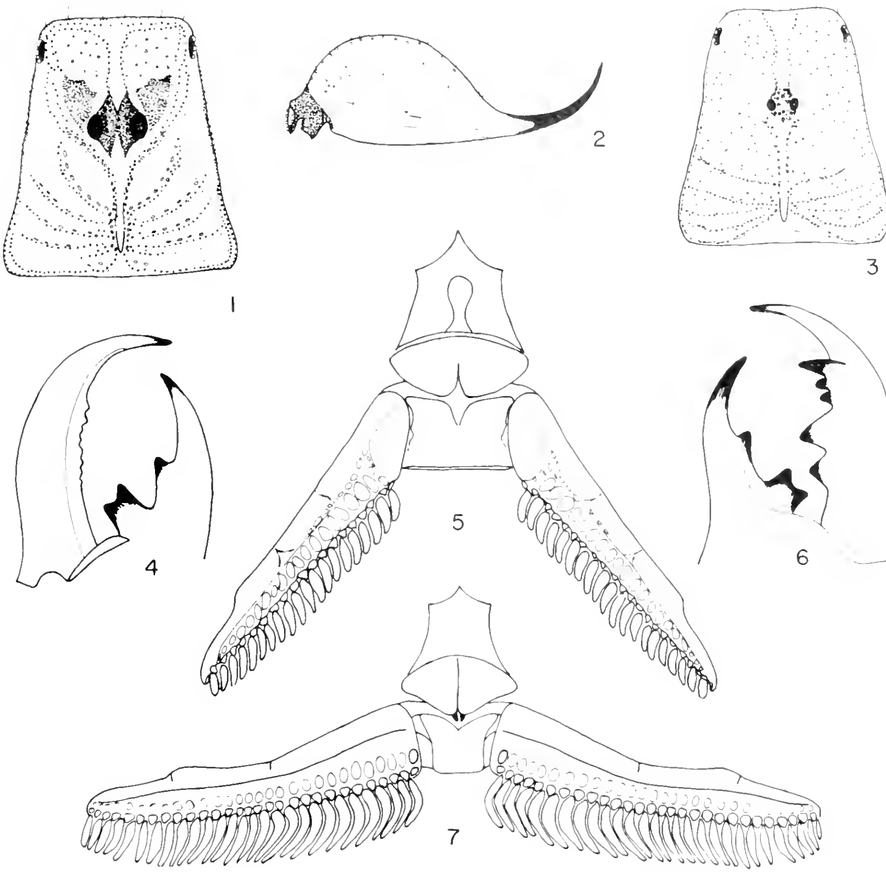
   Vesicle of telson with only a few scattered hairs or bristles ... 7

7. Hand of pedipalp (Fig. 9) with fixed finger somewhat longer than palm ... *Vejovis confusus* Stahnke

   Hand of pedipalp (Fig. 11) with fixed finger very much longer than palm ... *Vejovis wupatkiensis* Stahnke

8. Hand of pedipalp (Fig. 8) robust, with palm as broad as length of fixed finger; fingers relatively short, with inner margins sinuate or angled; preabdomen with dark pattern ... *Vejovis boreus* (Girard)

   Hand of pedipalp (Fig. 10) more slender, with palm about half as broad as fixed finger; fingers more slender, with inner margins not much angled; preabdomen pale ... *Vejovis becki*, new species

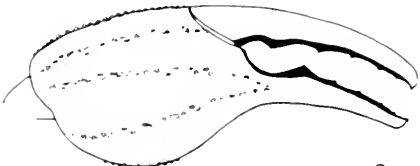


Figs. 1, 2. *Vejovis becki*, new species. 1. Carapace of female. 2. Sting of female, lateral view.
Fig. 3. *Vejovis confusus* Stahnke, carapace of female.
Figs. 4-7. *Vejovis becki*, new species. 4. Right chelicera of female, ventral view. 5, Sternum, genital operculum and combs of female. 6. Right chelicera of female, dorsal view. 7. Sternum, genital operculum and combs of male.

Family Vejovidae

Genus *Vejovis* Koch

The genus *Vejovis* comprises the largest and most diverse generic group of the largely American family Vejovidae. Species are numerous in the United States and Mexico but none occurs in tropical America. In the past the genus has been restricted to mostly small species with numerous middle lamellae and numerous teeth in the pectines and without so-called teeth on the lower margin of the movable finger of the chelicera. This last feature is subject to considerable variation, is inexplicit as now used, and has occasioned the formation of genera here considered superfluous. In some, mostly small species of the genus as here used, the lower cheliceral margin of the movable finger is essentially smooth. In other mostly larger species it is irregularly dissected into trivial, unequal lobes or teeth, and finally in large or robust species it is frequently dissected into irregular lobes or series of dark teeth. All these extremes can be found in species groups otherwise close-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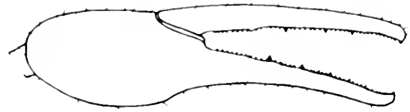
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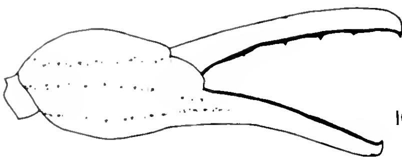
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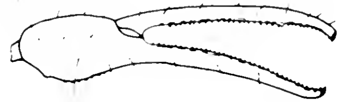
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Fig. 8. *Vejovis boreus* (Girard), left chela of female dorsal view.
Fig. 9. *Vejovis confusus* Stahnke, left chela of female, dorsal view.
Fig. 10. *Vejovis becki*, new species, left chela of female, dorsal view.
Fig. 11. *Vejovis wupatkiensis* Stahnke, left chela of female, dorsal view.
Fig. 12. *Vejovis confusus* Stahnke, sting of female, lateral view.
Fig. 13. *Vejovis hirsuticauda* Banks, sting of female, lateral view.

ly bound together by many other features. It seems clear that the genus *Uroctonus*, seemingly distinctively based on a smaller number of middle lamellae and teeth on the cheliceral carina, and *Paruroctonus*, based on a larger number of such lamellae and cheliceral teeth, are merely opposite ends of a series with many intergrading elements. To maintain these genera would demand further subdivision of *Vejovis* into other equally valid taxa and result in undesirable fragmentation of a group at present not excessive in size. In this paper *Paruroctonus* is regarded merely as a subgenus, as one of the species groups of *Vejovis*, and easily contained within the *boreus* group. A corollary is the necessity to incorporate the whole subfamily Uroctoninae into the Vejovinae.

Vejovis confusus Stahnke

Figures 3, 9, 12, 20, Table 1

Vejovis confusus Stahnke, 1940, Iowa State College Jour. Sci., vol. 15, p. 101.

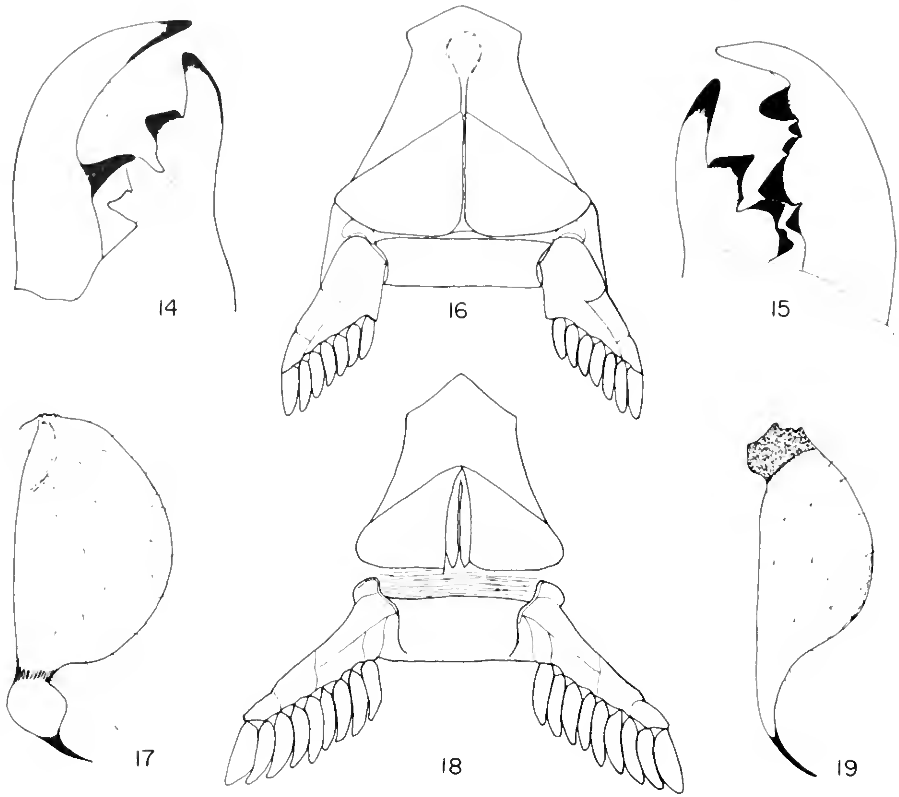
Vejovis flavus Stahnke, 1956, Scorpions, Second Edition. Arizona State College, Tempe, Arizona, p. 27, fig. 10.

Type data. Syntypes from Coolidge, Mesa, Superior, Tucson, Wichenburg, and Casa Grande National Monument in Arizona. In Arizona State University collection (H. L. Stahnke).

Diagnosis. This very common species, which has been confused with *Vejovis flavus* Banks of New Mexico, is of small to median size and sometimes attains 55 mm in length. The whole body varies from yellow to orange-brown and

Table 1. Measurements (in millimeters) of species of *Vejovis*.

	wupatkiensis		*hirsuticauda*		*confusus*	
	Female	Male	Female	Male	Female	Male
Total length	34.0	25.9	36.5	35.1	47.3	39.1
Carapace						
Length	4.2	3.4	4.5	4.7	5.8	4.9
Width at side eyes	2.3	1.8	2.3	2.2	3.5	2.7
Width at caudal edge	4.1	3.0	3.8	3.8	5.5	3.8
Preabdomen						
Length	10.3	6.5	12.0	9.0	14.0	10.0
Width	4.3	3.0	4.2	3.8	5.3	4.2
Postabdomen, length	19.5	16.0	20.0	21.4	27.5	24.2
Segment I						
Length	2.2	1.7	2.2	2.5	3.0	2.7
Width	2.3	1.9	2.0	2.2	3.4	2.5
Segment II						
Length	2.4	2.0	2.6	3.0	3.2	3.0
Width	2.2	2.0	1.8	2.0	3.3	2.5
Segment III						
Length	2.7	2.1	2.9	3.1	3.5	3.0
Width	2.1	2.0	1.7	1.8	3.3	2.5
Segment IV						
Length	3.0	2.7	3.5	3.8	4.8	4.0
Width	2.0	1.8	1.5	1.7	3.5	2.6
Segment V						
Length	4.7	3.8	4.5	5.0	6.3	5.5
Width	1.8	1.8	1.3	1.5	3.5	2.6
Telson, length	4.5	3.7	4.3	4.0	6.7	6.0
Vesicle						
Length	2.7	2.2	2.5	3.0	4.5	3.7
Width	1.4	1.3	0.9	1.0	3.2	2.3
Depth	1.2	1.0	0.9	1.0	2.3	1.9
Spine, length	1.5	1.3	1.5	1.5	2.0	1.7
Pedipalp	16.1	12.5	13.6	14.0	18.4	15.7
Femur						
Length	4.2	3.2	3.3	3.5	4.7	4.1
Width	1.0	0.8	1.3	1.3	1.5	1.1
Tibia						
Length	4.5	3.5	3.5	3.5	5.2	4.8
Width	1.3	1.0	1.5	1.5	1.9	1.4
Hand						
Length	7.4	5.8	6.8	7.0	8.5	6.8
Width	1.5	1.3	2.0	2.8	2.2	1.5
Depth	1.3	1.1	2.3	2.7	2.0	1.4
Palm length	3.1	2.5	4.0	4.5	4.0	3.2
Moveable finger, length	5.0	3.7	3.7	3.5	5.3	4.6
Combs, number of teeth	15-16	17	15-16	16-18	13-17	17-19



Figs. 14, 15. *Hadrurus arizonensis* Ewing. 14. Right chelicera of female, ventral view. 15. Right chelicera of female, dorsal view.

Figs. 16-19. *Anuroctonus phaeodactylus* (Wood). 16. Sternum, genital operculum and combs of female. 17. Sting of male, lateral view. 18. Sternum, genital operculum and combs of male. 19. Sting of female, lateral view.

usually lacks darker contrasting markings. This is a variable scorpion in morphological features. Smaller specimens are usually slender, but larger and presumably older specimens have thick abdomens. The telson is rather thick but bears a short sting. In females with thick cauda the telson is often heavy and conspicuously granulated. The fingers of the pedipalpi are long and slender as are the palms of the hands which are smooth or very weakly granulated.

Coloration. Base color yellowish to dusky brown in preserved specimens; appendages and underside paler. Carapace without contrasting markings except for black eyes and tubercles. Preabdomen and postabdomen typically unmarked with granulated keels and black sting providing some contrast. Males somewhat paler, often with narrow black seam outlining tergites.

Structure. Similar in both sexes but male more slender with proportionately longer postabdomen.

Carapace: Slightly longer than broad in female, considerably longer in male (Fig. 3). Anterior margin essentially straight, set with six suberect bristles. Surface granulose, with rows and clusters of large granules over most areas. Median groove distinct to near caudal edge and shallow trench passing forward to margin. Median eyes small, set on low tubercle; width of median diad about one-fifth the width of cara-

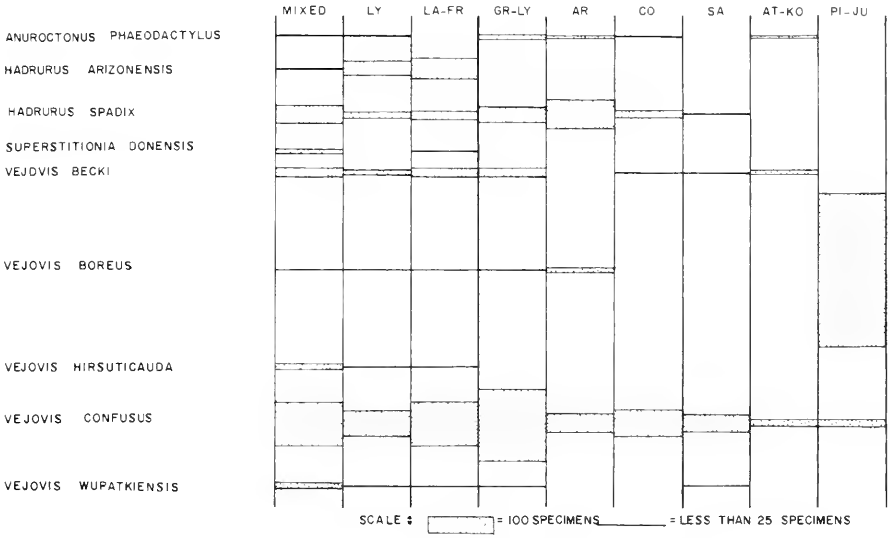


Fig. 20. Distribution and relative abundance of scorpions in the various plant communities.

pace at this point. Lateral eyes of each side three in number, of which posterior one is smaller and set above others.

Preabdomen: Tergites granulose, with several transverse rows of heavy granules in posterior half of each segment; tergite VII with heavy, granulose keels.

Postabdomen: Dorsal and superior lateral keels prominent, set with heavy granular teeth, of which last one on each segment only slightly enlarged. Inferior lateral keels distinct and granular but those on basal segments less prominent. Inferior median keels weak and smooth on first, stronger and smooth on second, partially granulate on third, and strong and granulose on apical segments. Fifth segment slightly longer than carapace in both sexes, with numerous coarse granules between ventral keels.

Telson: Sting short, curved, about half as long as vesicle (Fig. 12). Subaculear nodule present. Vesicle not fully as wide as segment V of postabdomen, set with rows of conspicuous, rounded granules.

Pectines: Those of female small; median piece deeply grooved in front half, two-thirds as long as wide; middle lamellae consisting of about 10 rounded pieces; pectinal teeth short, broad at apices, numbering 13 or 14. Those of male much larger and broader as usual; median piece as in female; middle lamellae about 12 rounded, less distinct pieces; pectinal teeth larger, curved, numbering 17 to 19.

Genital operculum: Similar to that of *Vejovis becki* (see figs. 5, 7).

Chelicerae: Tooth structure typical for genus; lower margin of movable finger with keel essentially smooth, weakly crenate under higher power.

Pedipalps: Femur of female about three times as long as broad, with all carinae prominent and granular. Tibia not fully three times as long as broad, thickened below, with carinae distinct and granulate. Hand essentially smooth, without distinctive keels (Fig. 9). Inner keel of both fixed and movable fingers with unequal series of close-set brown teeth, broken into six groups by enlarged teeth flanked by six large supernumerary teeth. Hand of male thinner than that of female.

Distribution and abundance. Known from southern Nevada and the warmer parts of Arizona and adjacent California. This was the most abundant and widely distributed species at the test site. It was taken in areas 1, 4, 5, 6, 10, 12, A, B, C, E, J, M, and T. It was found in every plant community, but was predominant in Grayia-Lycium, Larrea-Franseria, and Mixed.

It was least abundant in Atriplex-Kochia and Pinyon-Juniper. A total of 858 specimens was collected.

Sex ratio and seasonal occurrence. Many of our early identifications did not include sex differentiation. However, from a random sample of about 200 specimens, there were about half again as many males as females. Adult males were active from May through September, predominantly in July and August. Females were active from April through September, predominantly in June. Immature scorpions were taken from May through September, predominantly in June. Other scorpions not determined to sex were taken in small numbers as early as March and as late as November.

Vejovis wupatkiensis Stahnke

Figures 11, 20, Table 1

Vejovis wupatkiensis Stahnke, 1940, Iowa State College Jour. Sci., vol. 15, p. 101.

Type data. Male and female syntypes from the Wupatki National Monument near Flagstaff, Arizona. In the collection of Arizona State University (H. L. Stahnke collection).

Diagnosis. This is a small, slender scorpion which rarely exceeds 35 mm in length. The entire body is uniform yellow to orange-brown without contrasting darker markings. The smooth carapace, which has the front edge essentially straight, is finely granular with few conspicuous larger granules. The eyes are small and the median diad covers little more than one-fifth the width of the carapace at that point. The conventionally toothed chelicerae have the lower margin of the movable finger essentially smooth. The hands of the pedipalp bear inconspicuous keels which are set irregularly with granules (Fig. 11). The fingers are very long and the movable finger is nearly twice the length of the palm. All keels on the postabdomen are distinct and granular except the inferior median keels on segments I and II which are very weak. The sting of the telson is two-thirds the length of the vesicle and often bears a subaculear tubercle or distinct tooth beneath the base.

Distribution and abundance. Known from northern Arizona westward to Nevada and adjacent California. This species is seventh in abundance at the test site. Geographically it was found in areas I, 4, 5, A, C, J and M. Ecologically it was found predominantly in the Mixed community, and infrequently in Grayia-Lycium, Larrea-Franseria, Lycium, and Salsola. Twenty-eight specimens were collected.

Sex ratio and seasonal occurrence. Males and females were taken in about equal numbers, with females slightly predominant. Adult males were active in July, August, October, and November, and females the same months plus March, June, and September. Immature scorpions were taken in June, July, and August.

Vejovis hirsuticauda Banks

Figures 13, 20 Table 1

Vejovis hirsuticauda Banks, 1910, Pomona College Jour. Ent., vol. 2, p. 189, fig. 81J. Ewing, 1928, Proc. U. S. Natl. Mus., vol. 73, art. 9, p. 10 (*Vaejovis*).

Type data: Female type from San Bernardino County, California. In the Museum of Comparative Zoology, Harvard University.

Diagnosis. The small, uniform yellow to orange-brown scorpion shows little sexual dimorphism and rarely exceeds 40 mm in length. The carapace, which has a small but distinct emargination in front, and preabdomen are studded with distinct coarse granules over much of the surface. All the carinae on the postabdomen are well developed and evenly set with small, pointed denticles. The thin postabdomen diminishes gradually from base to tip and ends with an elongated telson liberally clothed with a thin brush of fine hairs mostly on the ventral surface (Fig. 13). This distinctive feature makes the common name "hairy-tailed scorpion" very appropriate. The hands of the pedipalp are considerably incrassated and the distinct keels are set with coarse granules. The fingers are of moderate length with the movable one about equal to the length of the palm. The lower margin of the movable finger of the chelicera is essentially smooth and bears only small points and irregularities under high power. The combs are of average size for the group, and the teeth vary from 15 to 16 in females and 16 to 18 in males.

Distribution and abundance. Known from southern Nevada and adjacent California, southward into Baja California. This species is next to the least abundant at the test site. It is geographically limited to areas 5, A, C, and J. Ecologically it was found predominantly in the Mixed community, and infrequently in Larrea-Franseria and Lycium. Only 18 specimens were taken.

Sex ratio and seasonal occurrence. Males and females were taken in about equal numbers.

Adult males were active in June, July, September, and October, and females during the same months plus May. Immatures were found in June and October.

Vejovis boreus (Girard)

Figures 8, 20; Table 2

Scorpio (Telegonus) boreus Girard, 1854, *in* Marcy, Exploration of the Red River of Louisiana in the year 1852, p. 257.

Vejovis silvestrii Borrelli, 1908, Bol. Lab. Zool. Gen. Agraria, Portici, vol. 3, pp. 225-227.

Vejovis boreus Ewing, 1928, Proc. U. S. Natl. Mus., vol. 73, art. 9, p. 12. Gertsch, 1958, Amer. Mus. Novitates, no. 1903, p. 6.

Type data. The Valley of the Great Salt Lake. Specimen collected by Captain Howard Stansbury.

Diagnosis. This is a medium-sized scorpion of conventional pale yellow coloration with a V-shaped black marking centered on the median eyes, and dusky transverse bands on the segments of the preabdomen. Specimens from the Nevada Test Site are lightly marked with black as compared with the bold, black pattern of examples from the California mountains. The median eyes are average in size, set on a low tubercle, and the width of the diad is at most one-fourth the width of the median eyes at that point. The inferior median keels of the cauda are essentially obsolete on segments I to III, but their presence is indicated by a pair of diffuse, brown bands. The thick hands of the pedipalpi are provided with well-marked ridges bearing numerous granules (Fig. 8). The chelicerae are rather small and have the keel on the lower margin of the movable finger irregularly crenate as in *becki*. The pectinal tooth count is variable, in females being about 19 and in males 25 to 30. For comparative measurements, see Table 2.

Distribution and abundance. This widespread species, called "northern scorpion" by Ewing in 1928, ranges widely from the southern Canadian Provinces (Saskatchewan to British Columbia) southward into Mexico. This was the fifth most abundant scorpion at the test site. It was found in areas 5, 10, 12, E and J. It was collected in all the plant communities except Atriplex-Kochia, Coleogyne, and Salsola, although it occurred in abundance only in the Pinyon-Juniper. Sixty specimens were collected.

Sex ratio and seasonal occurrence. Males and females were taken in a ratio of 6:1. Adult males were active from June through September, predominantly in the latter three months. Females were active also from June through September. Immatures were taken only in July.

Vejovis becki, new species

Figures 1, 2, 4-7, 10, 20, Table 2

Type data. Male holotype from the Nevada Test Site, approximately 34 miles due north of Mercury, Nye County, Nevada, taken 21 July 1961. (Brigham Young University Ref. No. 275, Collection Code 10DA11C). Captured in a sunken can trap in a *Coleogyne ramosissima* plant community (refer to Allred, Beck, and Jorgensen, 1963b); deposited in American Museum of Natural History.

Diagnosis. This species belongs to the *boreus* group of *Vejovis*, which comprehends in addition to the typical species (*boreus* Girard and *aquilonalis* Stahnke) the three North American species assigned to the genus *Paruroctonus* (*gracilior* Hoffman, *mesaensis* Stahnke, and *vachoni* Stahnke). *Vejovis becki* agrees with the first two species of this latter group in having the dark median eyes greatly enlarged so that the diad is about one-third the width of the carapace at that point. It is a much smaller and more slender species than *vachoni* and far less slender than *mesaensis*, from which it is readily separated by the lesser number of teeth in the pectines and the lack of distinct dark granules or teeth at the base of the fixed finger of the chelicera. In general appearance it resembles *gracilior*, but the chela of the pedipalp is far thinner with much longer fingers. *Vejovis becki* is considerably paler and never bears the dark markings on the preabdomen present in *boreus*. Measurements are given in Table 2.

Coloration. Base color yellow to orange-brown in preserved specimens of both sexes, but legs and pectines pale yellow and flexible cuticula white. Carapace with dark pattern as follows: Eyes and eye tubercles black; dark central dusky patch enclosing median eyes and from it inconspicuous dusky shadings radiating forward and to sides. Preabdomen and postabdomen unmarked; tip of sting dark red.

Structure. Similar in both sexes but males as usual in this group smaller and somewhat more slender as shown in comparative measurements.

Carapace: Clearly longer than broad in both sexes (Fig. 1). Anterior margin essentially straight, set with six suberect bristles. Much of surface finely granulose, with rows of coarser

Table 2. Measurements (in millimeters) of species of *Vejovis* and *Anuroctonus*.

	V. boreus		*V. becki*		*A. phaeodactylus*	
	Female	Male	Female	Male	Female	Male
Total length	44.5	46.1	45.9	37.3	58.7	62.2
Carapace						
Length	5.5	5.5	5.7	4.3	10.0	9.5
Width at side eyes	3.3	3.3	3.5	2.7	6.2	5.5
Width at caudal edge	5.2	5.2	5.0	3.8	9.0	8.3
Preabdomen						
Length	14.5	12.0	13.7	9.0	17.0	20.0
Width	6.0	5.5	5.5	4.2	8.7	8.5
Postabdomen, length	24.5	28.6	26.5	24.0	31.7	32.7
Segment I						
Length	2.5	3.0	2.7	2.7	3.0	3.0
Width	2.8	3.0	2.7	2.2	4.0	3.7
Segment II						
Length	2.7	3.4	3.0	3.0	3.5	3.5
Width	2.5	2.9	2.4	2.1	3.7	3.5
Segment III						
Length	3.0	3.8	3.3	3.3	4.5	4.3
Width	2.5	2.8	2.3	2.0	3.6	3.3
Segment IV						
Length	4.0	4.5	4.3	4.0	5.5	5.5
Width	2.5	2.6	2.1	1.8	3.5	3.3
Segment V						
Length	6.0	7.2	6.5	5.7	7.5	7.7
Width	2.5	2.7	2.3	1.7	3.5	3.0
Telson, length	6.3	6.7	6.7	5.3	7.7	8.7
Vesicle						
Length	4.5	4.5	4.3	3.5	5.0	6.4
Width	2.6	2.6	2.5	1.7	2.7	3.7
Depth	2.3	2.0	2.2	1.4	2.7	4.3
Spine, length	2.3	2.2	2.3	1.8	2.5	2.9
Pedipalp	15.4	18.3	17.2	14.8	29.5	29.0
Femur						
Length	4.3	4.8	4.5	4.0	6.0	6.0
Depth	1.4	1.5	1.3	1.0	2.7	3.0
Tibia						
Length	4.8	4.8	4.5	4.0	7.0	7.5
Depth	1.7	1.9	1.7	1.2	3.5	4.3
Hand						
Length	6.3	8.7	8.2	6.8	16.5	15.5
Width	3.3	3.0	1.7	1.7	6.0	5.3
Depth	2.7	4.0	1.9	1.8	5.0	6.3
Palm length	4.5	5.0	4.0	3.5	9.0	10.0
Movable finger, length	5.3	5.6	5.2	4.0	8.8	8.5
Combs, number of teeth	19	25-30	17-21	24-29	5-7	8-10

granules forming inconspicuous lines and patches. Median groove distinct from median eyes to posterior margin, with flanking elevations set with coarse granules. Median eyes large, on conspicuous oval tubercle; width of median diad about one-third the width of carapace at this point. Lateral eyes of each side three in number, of which posterior one is smallest.

Preabdomen: Traces of weakly granulated median keel on tergites I to VII still persistent. Tergites finely granulose throughout (essentially smooth under low power), with transverse rows of inconspicuous granules on posterior edges of tergites and more conspicuous scattered series on posterior tergites.

Postabdomen: Dorsal and superior lateral keels prominent, surmounted with rows of serrate to crenate teeth of regular size. Inferior median keels essentially obsolete on segments I to III, represented on segment IV by slight, smooth keels, and on segment V with single granulate median keel. Inferior lateral keels on segments I to III largely smooth, on segment IV smooth with series of weak granules in distal half, on segment V with series of serrate teeth becoming larger apically. Segment V slightly longer than carapace in female, considerably longer in male.

Telson: Sting moderately curved, shorter than vesicle (Fig. 2). Subaculear nodule not present. Vesicle about as wide as segment V of postabodmen.

Pectines: Those of female small and of medium width as shown in Fig. 5; median piece broader than long; middle lamellae consisting of about 20 small oval pieces; fulcra small, subtriangular; pectinal teeth of medium length and stoutness, numbering 17 to 21 in three females; those of male much larger and broader (Fig. 7); median piece about as long as broad; middle lamellae about 30 small round to oval pieces; pectinal teeth long, curved, numbering 24 to 29 in 20 males examined.

Genital operculum: In the female with a longitudinal fissure but free only in posterior fourth (Fig. 5); in the male free for most of length (Fig. 7).

Chelicerae: Tooth structure typical, that of female shown in figures 4 and 6; upper margins of both fingers with strong teeth; lower margin of fixed finger essentially obsolete, with weak keel and faint granulations; lower margin of movable finger with distinct thin keel of which edge is irregularly crenate to form weak pale rounded denticles.

Pedipalps: Femur of female about three times as long as broad, with all carinae distinct and granulated. Tibia not fully three times as long as broad, narrowed at base, inflated at center, with all carinae granulated. Chela rather thin with long fingers (Fig. 10). Hand with low carinae set with small granulations. Inner keel of fixed finger with thick series of close-set brown teeth broken into six groups by enlarged teeth, adjacent to which are six large supernumerary teeth. Inner keel of movable finger like fixed finger but bearing additional supernumerary tooth near distal end. Male like female but an additional supernumerary tooth often present.

Distribution and abundance. Known from southern Nevada and adjacent California. This species was the third most abundant taken at the test site. It was widely distributed geographically, found in areas I, 4, 5, 6, 10, C, E, and J. Ecologically it was also widely distributed, found in all the plant communities except Artemisia and Pinyon-Juniper. It was predominant and about equal in numbers in Atriplex-Kochia, Grayia-Lycium, Larrea-Franseria, and Mixed communities. A total of 114 specimens was collected.

Sex ratio and seasonal occurrence. Males and females were taken in a ratio of 2:1. Adult males were active from May through September, predominantly June. Females were active from March through November. Immature specimens were taken from April through September, predominantly in July and August.

Genus *Anuroctonus* Pocock

This exclusively American genus is represented by the single distinctive species diagnosed below. *Anuroctonus* differs from the *mordax* group of *Vejovis* only in the following features: The fourth segment of the postabdomen completely lacks inferior ventral keels whereas those on the preceding segments are distinct and granular. The sting of the telson in most males is inflated at the base. The median lamellae of the pectines consist of a few irregular pieces.

Anuroctonus phaeodactylus (Wood)

Figures 16-20; Table 2

Centrurus phaiodactylus Wood, 1863, Proc. Acad. Nat. Sci. Philadelphia, p. 111; 1863, Jour. Acad. Nat. Sci. Philadelphia, ser. 2, vol. 5, p. 372.

Anuroctonus phaeodactylus Pocock, 1902, Biologia Centrali-Americana, Arachnida, Scorpiones, Pedipalpi and Solfugae, p. 14, pl. 3, figs.

1-1e, pl. 1, figs. 1-1e. Ewing, 1928, Proc. U. S. Natl. Mus., vol. 73, art. 9, p. 14. Hoffmann, 1931, An. Inst. Biol. Mexico, pp. 403-405. Gertsch, 1958, Amer. Mus. Novitates, no. 1903, p. 14.

Type data. Male type from Utah Territory. Presumed to be in the U. S. National Museum (Smithsonian Museum).

Diagnosis. This stout scorpion is of medium to large size and often attains a length of about 90 mm from front of carapace to tip of sting. In size it is overshadowed by species of *Hadrurus*. Its base color is dull yellow to dark brown, and the heavy pedipalps bear short black fingers. The front margin of the rough, granular carapace is provided with a shallow V-shaped emargination. The median eyes are rather small with the diad equaling about one-sixth the width at that point. The vesicle of the telson is large, shining yellow, and in typical males the black sting is inflated at the base (Fig. 17). In some smaller males the sting resembles that of the female in being drawn out evenly as a curved spine (Fig. 19). The ventral keels on the postabdomen are distinct and coarsely granular on all segments but IV where they are obsolete. The heavy hands are smooth above with smooth keels, but the sides and ventral surfaces bear coarse granules. The chelicerae are large, toothed as in *Vejovis*, and the lower margin of the movable finger bears one to three small, pale teeth near the base. The genital operculum is very large in the female, is deeply grooved longitudinally, but remains tied for most of the length (Fig. 16). In the male the genital operculum is nearly as large as that of the female, is deeply grooved to form free valves, and presents distinct papillae at the posterior edge (Fig. 18). The pectines are rather small, separated by a large median piece, and the teeth are few in number—5 to 6 in females, 8 to 10 in males.

Distribution and abundance. Known from Utah, southern Nevada, and southern California to Baja California. This scorpion is not considered to be abundant at the test site, ranking sixth in occurrence. However, it is widely distributed geographically, found in areas 1, 4, 5, 6, 12, C, J, and T. Ecologically, it was most abundant in the Gravia-Lycium community, next common in Artemisia and Atriplex-Kochia, and was taken only rarely in Coleogyne, Lycium, and Mixed communities. Forty-eight specimens were taken.

Sex ratio and seasonal occurrence. Males and females were taken in a ratio of 13:1. Adult males were active from July through September, most predominantly in August. Adult females were taken in small numbers only in January, March, and June. Immature scorpions were taken in about equal numbers in March, June, and October.

Genus *Hadrurus* Thorell

The presence of a single, large, sharp tooth on the lower margin of the movable finger of the chelicera quickly identifies this North American genus (Fig. 14). The genital operculum is grooved longitudinally with the two valves free in both sexes, but genital papillae are lacking in males as well as females.

The broader than long middle piece of the comb bears a deep groove in front at the middle and is similar in both sexes. The combs are large, supplied with numerous teeth as in species of the *Vejovis boreus* group, and show the sexual dimorphism of that genus, those of the male being larger with longer, more numerous teeth. The presence of many large bristles on the appendages and distal segments of the postabdomen, far more numerous than in our other scorpions, has occasioned the popular name "giant hairy scorpions" for these, our largest and in some ways most distinctive scorpions.

The systematic status of the three populations of *Hadrurus* in the United States (*hirsutus* Wood, *arizonensis* Ewing, and *spadix* Stahnke) at present given specific status presents a difficult and interesting problem. There seems to be little or no morphological difference between them and they largely replace each other geographically. The color features separating *hirsutus,* which is a large form with pale preabdomen largely confined to southern California and adjacent Mexico, from the commoner, widespread darker *arizonensis* are not so precise as one would wish. It seems likely that *arizonensis* is merely a subspecies of *hirsutus.* The status of *spadix* remains obscure but it seems probable that it deserves specific status. The all-dark color of the carapace and trunk is an invariable feature of adults and young specimens of many sizes. There are no intergrades between *spadix* and *arizonensis* and they occur together at the Nevada Test Site.

Hadrurus arizonensis Ewing

Figures 14, 15, 20, Table 3

Hadrurus hirsutus arizonensis Ewing, 1928, Proc. U. S. Natl. Mus., vol. 73, p. 8.

Hadrurus arizonensis Stahnke, 1945, Amer. Mus. Novitates, no. 1298, p. 6; 1956, Scorpions.

Table 3. Measurements (in millimeters) of species of *Hadrurus* and *Superstitionia*.

	H. arizonensis		*H. spadix*		*S. donensis*	
	Female	Male	Female	Male	Female	Male
Total length	102.6	108.5	96.2	104.0	23.8	22.6
Carapace						
Length	13.5	13.0	11.0	13.0	2.8	2.8
Width at side eyes	10.7	9.0	7.0	8.3	1.7	1.7
Width at caudal edge	13.5	13.0	11.0	13.0	2.8	2.8
Preabdomen						
Length	26.0	26.5	30.0	27.5	8.5	5.7
Width	14.0	14.5	13.0	13.0	3.0	3.2
Postabdomen, length	63.1	68.0	55.2	63.5	12.5	14.1
Segment I						
Length	7.5	8.5	6.7	8.0	1.2	1.2
Width	7.0	6.7	6.1	7.0	1.8	2.1
Segment II						
Length	8.7	9.5	7.5	9.0	1.3	1.3
Width	6.5	6.3	6.8	6.2	1.7	2.0
Segment III						
Length	9.4	10.5	8.0	9.5	1.5	1.6
Width	6.3	6.3	6.8	6.0	1.7	2.0
Segment IV						
Length	10.5	11.5	9.5	10.5	2.2	2.6
Width	6.1	6.3	5.6	6.2	1.7	2.0
Segment V						
Length	13.0	14.0	11.0	13.0	3.3	3.7
Width	5.3	6.0	5.5	6.0	1.2	2.0
Telson, length	14.0	15.0	12.5	13.5	3.0	3.7
Vesicle						
Length	10.0	10.0	7.5	9.0	2.3	2.6
Width	6.2	5.8	5.3	6.5	1.6	1.7
Depth	5.8	5.5	4.8	5.7	1.2	1.3
Spine, length	4.0	4.5	4.5	4.5	0.8	1.0
Pedipalp, length	41.0	43.0	35.5	42.5	8.0	8.0
Femur						
Length	10.0	11.0	8.8	10.5	2.0	2.0
Width	3.5	3.3	2.8	3.2	0.7	0.7
Tibia						
Length	12.0	12.0	10.0	12.0	2.3	2.3
Width	4.6	4.3	3.8	4.0	1.0	1.1
Hand						
Length	19.0	20.0	16.7	20.0	3.7	3.7
Width	6.5	6.3	5.0	5.7	1.2	1.8
Depth	5.0	4.5	4.0	4.3	1.2	1.7
Palm length	10.0	9.5	7.5	9.5	2.3	2.3
Movable finger, length	13.0	13.3	11.7	13.6	2.0	2.0
Combs, number of teeth	27-33	33-39	27-33	34-39	±6	±6

Type data. Female type from Papago Saguaro National Monument. In the U. S. National Museum.

Diagnosis. This large species when fully grown averages about 100 mm in length and often attains 115 mm. The carapace is dusky brown except in front of the median eyes, where most of the interocular space is yellow. The black median eyes lie at the center of a crescentric darker marking which margins the pale front portion. The preabdomen is dusky brown, but the postabdomen and the appendages are yellow to light yellowish brown. The carapace, which is widely rounded in front, is evenly and coarsely granulated, and similar granulations occur over the seventh segment of the preabdomen and on portions of the preceding segments. Nearly all keels on the postabdomen are distinct and granular except the inferior ventral keels, which are smooth in segments I to III. The telson is thick, covered with long red bristles, and the black sting is only about half as long as the vesicle. The hands of the pedipalps are weakly keeled and granulated mainly along the rounded sides. The inner edges of the long fingers bear nine slightly oblique rows of granular denticles, each row marked by an enlarged granule, and nearby large supernumerary granules, nine on the movable finger and seven on the fixed one.

Distribution and abundance. Known from Arizona, southern Nevada, southern California, and southward into Sonora. This was the fourth most abundant scorpion at the test site, although it was somewhat limited geographically. It was found only in areas 5 and C. Ecologically it was most predominant in the Larrea-Franseria and Lycium communities. The only other community in which it occurred, even in small numbers, was Mixed. Ninety-four specimens were taken.

Sex ratio and seasonal occurrence. Males and females were taken in a ratio of 5 to 1. Adult males were active from June through September, most predominantly in August. Adult females were active in small numbers from May through September, with slight predominance in June and July. Immature scorpions were taken from June through September, with slight predominance in July.

Hadrurus spadix Stahnke

Figure 20; Table 3

Hadrurus spadix Stahnke, 1940, Iowa State College Jour. Sci., vol. 15, p. 102; 1945, Amer. Mus. Novitates, no. 1298, p. 4.

Type data. Syntypes from Kingman, Grand Canyon, and Wupatki National Monument, Arizona. One of the syntypes has been designated "type" and deposited in the U. S. National Museum.

Diagnosis. This large scorpion differs from *arizonensis* only in color features. The carapace is dark brown or black to the frontal margin, and the dark color continues back to cover the entire preabdomen. The postabdomen and legs are typically darker yellow or yellow-brown than are those of *arizonensis*.

Distribution and abundance. Known from northern Arizona, southern Utah and Nevada, and eastern Oregon (Baker County). This was the second most abundant at the test site, and was widely distributed. It was found in areas 1, 4, 5, 6, 10, C, J, M, and T. Ecologically it was most abundant in the Artemisia and Mixed plant associations. This species was also common in other communities except the Salsola. It was not found in Atriplex-Kochia or Pinyon-Juniper. A total of 238 specimens was taken.

Sex ratio and seasonal occurrence. Males and females were taken in a ratio of 6:1. Adult males were active from May through September, predominantly in July. Females were active from May through October, predominantly in June. Immatures were active from April through September, predominantly from July through September.

Family Chactidae

Genus *Superstitionia* Stahnke

The presence of only two lateral eyes on each side instead of the conventional three lateral eyes of all our other scorpions readily identifies this monotypic genus.

Superstitionia donensis Stahnke

Figure 20; Table 3

Superstitionia donensis Stahnke, 1940, Iowa State College Jour. Sci., vol. 15, p. 102; 1949, Ent. News, vol. 60, p. 243.

Diplops desertorum Mulaik and Higgins, 1944, Ent. News, vol. 4, p. 238, figs. 1-9.

Type data. Syntypes of *Superstitionia donensis* Stahnke from the Superstition Mountains, Arizona. In Arizona State University (Stahnke collection). Holotype of *Diplops desertorum* Mulaik and Higgins from 16 miles east of Tucson, Arizona. In University of Utah collection.

Diagnosis. This small species, which rarely exceeds 25 mm in length, is the only represent-

ative of the family Chactidae found in the United States. It was described and well illustrated by Mulaik and Higgins under the name *Diplops desertorum*, now a synonym. The base color is yellow to dark orange-brown on which is a black pattern as follows: Carapace mottled, with distinct crescentric dark markings on each side of the median eyes; preabdomen with three distinct black stripes, a single median which runs the full length and continues along the postabdomen to the aculeus, and one on each side margin which runs the length and is continuous along the sides of the segments of postabdomen, being somewhat broken; venter of postabdomen with less distinct median line or stripe on four basal segments; pedipalpi and legs with scattered dark lines and spots. The body is smooth and shining with poor development of the carinae. The postabdomen is stout and smooth except for the sixth segment which bears heavy granules on the rounded carinae. The first three segments of the postabdomen are wider than they are long. The hands of the pedipalpi are essentially smooth and moderately incrassated, and the fingers are short. The chelicera has the same dental formula as that of typical *Vejovis*, and the lower margin of the movable finger of the chelicera is essentially smooth. The combs of the female are short and stout, each one not much longer than the width of the median piece, and six teeth are present. Those of the male are somewhat longer, about twice as long as the width of the median piece, and also bear six teeth.

Distribution and abundance. Known from southern California, southern Nevada, Arizona, eastern New Mexico, and southward into Sonora and Baja California. This was the species most rarely collected at the test side, found only in areas 1, C, and J. It was found in two communities only—Grayia-Lycium and Mixed. Only thirteen specimens were taken.

Sex ratio and seasonal occurrence. Males and females were taken in about equal numbers. Adult males were collected in January, September, and October; and females in March, June, and October. Two immatures were taken in April and July.

ECOLOGICAL SUMMARY

Only two species may be considered as abundant at the Nevada Test Site—*Vejovis confusus* and *Hadrurus spadix*. These two were the most widely distributed geographically, although *Anuroctonus phaeodactylus, Vejovis becki*, and *V. wupatkiensis* were almost as widely distributed. The same also applies to the ecological distribution of the above species. The greatest numbers of species of scorpions were found in the Mixed, Lycium, Grayia-Lycium, and Larrea-Franseria communities, respectively. Fewest species were found in Atriplex-Kochia and Pinyon-Juniper. In almost all cases where sufficient numbers were taken to provide a reliable sample, the sex ratio was predominantly in favor of the males. Seasonally, the greatest populations of scorpions were active between June and September, with highest peaks occurring in July and August.

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